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REPORT OF THE COMMITTEE

ON

THE PRESERVATION OF TIMBER

PRESENTED AND ACCEPTED AT THE ANNUAL CONVENTION

OF THE

AMERICAN SOCIETY OF CIVIL ENGINEERS,

JUNE 25TH, 1885.

PRESENTED BY

THE SUMMERVILLE CREOSOTING WORKS.

PREFACE.

Although the preservation of timber has long been a subject of earnest study in countries older than our own, it is only within a comparatively few years that Americans have been obliged to consider the question. The rapid destruction of our forests and the consequent increase in the value of timber in its natural state, together with the trouble and expense of constant renewal, have made the study of timber preservation one of great importance. Consumers of lumber and timber are fast realizing that some method of preservation must be resorted to, and the question arises as to what it shall be. Where there is only trifling exposure to moisture, a variety of methods have been discovered that materially assist in prolonging the life of timber. Foremost among them come "Burnettizing" and "Kyanizing."

Both of these have been, in a measure, successful, where material treated has been used in dry places. But when there is to be constant exposure to dampness, and when destruction, not only from natural decay, but from marine worms must be guarded against, no manner of preservation has yet been discovered, save the one of creosoting.

In the annexed report will be found ample and convincing evidence to countenance this positive statement.

The process, which is generally well known, consists of the injection of heavy oil of tar by means of artificial pressure, and the value of this mode of treatment lies in the fact that the antisceptic used is not soluble in water, and is a poison to all marine insects and worms.

A vast number of products are derived from coal tar, and no established formula has been arranged determining exactly the oil best suited for timber preservation.

It seems certain that the lighter tar acids gradually disap-

pear, while it is to the bases or less volatile portions of the oil that the lasting benefits must be credited. Hence it is a matter of supreme importance that the heavier grades of oil should be used. Oil that when cool, becomes thick within the timber, clogging up the cells of the wood so that neither air, moisture nor life can get inside.

The process of creosoting first made known by Franz Moll, and practically introduced by Bethell in 1838, has been in constant use since that time, and in principle, is much the same now as then.

S. B. Boulton, an eminent English authority on this subject, writes: "Creosote, correctly so called, is the product of the destructive distillation of wood, and coal tar does not contain any of the true creosote, which has never been used for timber preserving." So it will be seen that the so called creosote oil has no true creosote in it.

The mechanical appliances for the introduction of the oil are almost identical in all the recognized creosoting works of to-day. It is necessary to expel the moisture and sap from the pores of the wood before any sufficient quantity of the antisceptic can be forced in, and to do this, super-heated steam with vacuum and pressure pumps must be used. No fixed standard regulating the quantity of oil necessary for effectual preservation can be relied upon.

A safe rule is to give the wood all the oil that it will absorb. In open grained, porous timber, the quantity will vary from 14 to 25 pounds, while timber of closer fibre will retain a less quantity.

It is very generally conceded, however, that coarse grained, sappy material is the more desirable because of its retention of larger amounts of oil. The failures that have attended the process can be plainly and clearly attributed to inexperienced and imperfect treatment.

Wherever the work has been done intelligently and well, the results obtained have perfectly demonstrated the value of this method of preservation over all others.

THE SUMMERVILLE CREOSOTING COMPANY.

The works of this company were built during the summer of 1882. They are located at Summerville, South Carolina, 22 miles from Charleston, on the line of the South Carolina Railway.

The works were erected for the purpose of creosoting piling, and are different in construction from any in operation elsewhere. Instead of a closed iron tank large enough to take in a load of eight or more piles, the cylinders at Summerville will take in but one at a time. They are built forty and fifty feet in length with an outside diameter of two and one-half feet. They are horizontal in position, filled with the requisite number of steam coils and connected one with another.

In this way each pile is treated by itself, and, it is claimed, more uniformly than if a number are put together in one load.

As a reason for this, it is argued that the logs before entering the cylinder are in a variety of conditions. Even if cut at the same time, apparently under the same conditions, and subjected to the same seasoning process, some will be found dryer than others, and some perhaps quite green. It is impossible to secure timber equally seasoned by natural means. Consequently each log requires different time of treatment, some needing a longer application of steam or the exertion of greater oil pressure, as the case may be. With the small cylinder all this can be carefully regulated, and no log turned out unless a fixed quantity of oil be observed. In a large cylinder no degree of regularity can be assured. Some have more oil than the requisite quantity; others less. For this reason, if for no other, the Summerville Works claim superiority. Another feature of difference is in the fact that commencing at either end any portion of a log can

be creosoted. As the section to be driven has no need of artificial preservation a considerable saving in cost can sometimes be effected. The cylinders are sealed at one end, while at the other the pile is introduced and a semi-spherical head is fitted around it. By having a number of heads, with openings of different diameters, any sized pile can be treated. The cylinders are readily made tight by caulking about the pile, or when timber is being treated a solid head is used.

All the requisite pumps for creating vacuum and producing pressure are in use, and it is the intention of the management that none but thorough and carefully treated material shall be turned out.

The works are situated in the midst of a thickly wooded pine country, and have the advantage of a large section of country from which to select straight and sound timber. The prices charged are as low as is consistent with perfect treatment, and a careful inspection of the methods employed and of the work accomplished is earnestly desired of those who contemplate using creosoted material.

As the works have been in operation so short a time, no testimonials of particular value can be given, but annexed will be found letters from those who have driven piling creosoted at Summerville.

Very respectfully,

FRED'K W. CROCKER, Agent.

Mr. ALFRED F. RAVENEL, President of the Northeastern Railroad of South Carolina, writes:

MR. F. W. CROCKER, AGENT
SUMMERVILLE CREOSOTING WORKS, Charleston, S. C.:

DEAR SIR: It affords me pleasure to say to you that the piles which were creosoted at your works some three years ago and used in the construction of the wharves of this company at Charleston, S. C., were recently examined by

Mr. J. W. Putnam, of New Orleans, and by him reported to me as being in excellent condition and showing no signs of injury by worms. Sufficient time has not yet elapsed to establish the efficiency of your creosoting process in resisting their attacks for a more extended period, but as the work was carefully done and is at this date in the condition already described to you, I have great confidence in its fully meeting all our expectations of it.

Yours very respectfully,

(Signed) A. F. RAVENEL, President.

Charleston, S. C., Dec. 31, 1885.

Mr. W. B. W. Howe, Jr., Chief Engineer of the Charleston and Savannah and Savannah, Florida and Western Railways, writes:

F. W. Crocker, Esq., Agent
Summerville Creosoting Works, Charleston, S. C.:

Dear Sir: I am in receipt of your letter of December 4th, and it gives me pleasure to state that you have creosoted for me upwards of 1,400 piles during the past three years which have been used in the waters around Charleston, S. C., and while I have every reason to believe that the work was thoroughly and conscientiously done, I do not think they have been exposed for a sufficient length of time to determine accurately and without question the efficacy of the process.

Yours very truly,

(Signed) W. B. W. HOWE, Jr.,
Chief Engineer.

Savannah, Ga., Dec. 29, 1885.

Mr. Howe is also Engineer of the Charleston Bridge Company, and under his direction, during 1885, 586 piles creosoted at Summerville were driven in the Ashley River

at Charleston, S. C. The majority of these were piles eighty feet in length, measuring about eighteen inches at butt and not less than ten inches at point, creosoted from forty-three to fifty feet each.

Mr. F. O. Maxson, Civil Engineer United States Navy, under whose direction the new government coaling wharf at Port Royal, S. C., has just been completed, writes:

Fred. W. Crocker, Esq., Agent
Summerville Creosoting Works, Charleston, S. C.:

Dear Sir: In reply to yours of the 4th inst., I would state that after a careful study of the various methods at present in use for the preservation of wood especially in marine structure, I am convinced that creosoting is the best when the oil is of good quality, the drying of the wood thorough, and the injection made under sufficient pressure to insure penetration.

Of the modes of application, I think that for piling, no other is so well adapted to insure the best and most uniform results as that of separate cylinders, which offers every facility for testing each individual case, and where employed with adequate vacuum and force pumps and heating apparatus, and with proper vacuum, pressure and steam gauges, it is in my opinion the best devised at the present time.

Very respectfully,

(Signed) FRANK O. MAXSON.

Boston, Mass., Dec. 18th, 1885.

Col. J. B. Peck, General Manager of the South Carolina Railway, and New York and Charleston Warehouse and Steam Navigation Company, writes:

MR. F. W. CROCKER, AGENT
SUMMERVILLE CREOSOTING WORKS, Charleston, S. C.:

DEAR SIR: This company has at its wharves 619 piles treated at your works put in during the years 1882 and 1883. Twenty of these were imperfectly treated, and we were so informed before they were driven, but as the need for the wharf then being constructed was pressing, we put them in. We find that these piles where the oil did not penetrate sufficiently, are eaten by the Teredo, but only in such places, the creosoted parts being still untouched. The remainder have not been touched by the Teredo, and I do not think will be.

Piles not creosoted at all driven at the same time, are so badly eaten by Teredo and Limnoria as to require renewal next summer.

I am of the opinion that your system of treating piles singly is greatly preferable to that of treating several piles in the same cylinder at the same time, inasmuch as it enables you to ascertain the exact amount of oil injected into each pile, and thus secures an uniformity of treatment, which, owing to the different degrees of moisture in several piles cannot be attained where a number are treated in the same cylinder.

Yours truly,

[Signed.] JOHN B. PECK,
General Manager.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

309.

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THE PRESERVATION OF TIMBER.

REPORT OF THE COMMITTEE ON THE PRESERVATION OF TIMBER, PRESENTED AND ACCEPTED AT THE ANNUAL CONVENTION, JUNE 25TH, 1885.

WITH DISCUSSION.

The committee on the "Preservation of Timber" was appointed early in 1880.

Even before the gathering of statistics on forestry for the census of that year, it had become evident to engineers, from the increasing price and growing difficulty in procuring good timber, lumber and railroad ties in many parts of the United States, that several of the sources of such supplies were being rapidly exhausted, and that as a measure of both private and national economy it would soon become necessary for us to resort to the artificial preparation of wood against decay, as had been successfully done for years in Europe.

The principal questions before the committee were to determine which methods of preserving timber against decay were most successful, and which were best adapted to the needs and current practice in this country.

Designing to base its report only upon well ascertained facts, the committee undertook to gather as fully as practicable the records of the experiments that had thus far been made in the United States, in order to compare them with each other, and with the results in Europe.

During the first year the committee accomplished but little. It had to overcome the public indifference which then existed on the subject, and the popular impression that probably no good would result from the investigation, as it was doubted whether there were any successful processes applicable to this country. It also had to ascertain where the much-scattered information desired was to be found.

This it was determined to do by circulars and correspondence, in order to find *who* possessed the data of past experiments, and *who* would be willing to impart it. For this purpose the committee issued some 2 000 circulars, with postal cards inclosed, on which a form of answer was printed. It corresponded with some 350 persons, gathered and studied some 55 pamphlets, examined 104 patents, and thus obtained the results of some 147 experiments, which are hereinafter tabulated and commented upon.

When this information began to come in, the committee found it very confusing. Not only were there the greatest possible differences in the opinions which were expressed, but the facts seemed to contradict each other. Apparently the same processes seemed to give different results, and these again differed from the European experience.

The committee, therefore, made a preliminary report to the Washington Convention in 1882, and asked for more time to ascertain how each experiment had been carried out, and to sift the evidence.

This was very tedious, both because there were few written records of these experiments and we had to rely upon personal recollections, and because the various persons who possessed such remembrance (and sometimes it required three or four to recollect the details of one experiment) had changed their business connection, and were scattered all over the country.

The committee here wishes to express its grateful thanks for the universal kindness and care with which its inquiries have been answered by the various gentlemen whose names will be found quoted as "authority" in the records of experiments (last column). Whatever value this report may prove to possess is due to their assistance.

Necessity for Preserving Timber.

The data on forestry gathered for the census of 1880 have made it apparent that the time has now arrived when railway and other interests must largely resort to the artificial preparation of wood, in many parts of the United States.

As something may be accomplished by economy in the use of timber and by preventing waste, the Washington Convention instructed the

committee to include the latter subject in its report. This was intrusted to Mr. Francis Collingwood, who, from past researches and present inclination, was best fitted for the task, and who has furnished a monograph on the subject, which will be found in Appendix No. 1, and to which particular attention is invited.

From this it appears that our Northern white pine forests, which less than a generation ago were considered as inexhaustible, now bid fair to yield but eleven years more of supply at the existing rate, and that there is a growing scarcity of wood suitable for railroad ties.

These facts must soon produce advancing prices. The farther, but still accessible, supplies are now being drawn upon, and as soon as they are exhausted prices will go up with a jump. Several such periodical advances have already taken place, and in the older States, lumber, timber and ties are ruling at about double the rates prevailing thirty or forty years ago, with a prospect that in less than half that time they will approximate European prices.

Timber has hitherto been so abundant and cheap in the United States that there has been but little inducement or economy in preserving it artificially against decay. It was known that the Europeans, who have been experimenting on the subject for more than a century, had accomplished decided success; but inasmuch as to be effective the work must be well done it was found here to be relatively too costly.

So long as wood was cheap, the cost of efficient preparation, including interest on plant and price of antiseptics, was so great in proportion to the ruling timber prices twenty or thirty years ago that timber preservation did not pay. It was cheaper to let it rot in the good old way, and many corporations and individuals, after trying experiments which were more or less successful, abandoned the work as not conferring benefits commensurate with the cost.

Fresh attention was attracted to the subject by the publication of Messrs. Colburn and Holley's report upon European Railways in 1858. In this very valuable treatise a chapter was devoted to sleepers, and to their preparation against decay. This brought about the erection of some wood-preparing works by the larger railways, and a plentiful crop of so-called inventions to cheapen the processes.

The chief efforts of this crop of inventors were either to discover some cheaper antiseptics, or to use a less quantity than had been found to be requisite in Europe. They also proposed to reduce the time of application. These efforts to produce effects with cheaper agents, or to apply the homeopathic principle of small doses to the preservation of timber, did not meet with success. The inventors patented sundry preparations and methods, took such jobs as they could obtain, sold whatever State and county rights they could, and retired from the field when the insufficiency or danger of their process became apparent. We will hereafter describe some of these processes, and it may fairly be ex-

pected, should the publication of this report lead to renewed attention to the subject of wood preservation, that there will be a new crop of inventions based on the method of "how not to do it."

It will hereafter be seen that some of the processes which have been successful abroad led to indifferent or unsatisfactory results in this country. The committee has endeavored to ascertain the causes of this, and found them in the unobservance of some of the conditions which have been found necessary to success in Europe. These relate to the time occupied in treatment, to the methods pursued, to the strength and quality of the solutions employed, and especially to the fact that the Europeans chiefly operate upon seasoned timber, while we have generally operated upon green or freshly cut timber, which requires a different treatment.

These various points will be touched upon in describing the principal experiments which have been conducted in this country, and will be found fairly to account for whatever differences have been found in the results—differences so great as to have led many managers of important interests to doubt whether any method of wood preparation against decay could be said to be successful.

Preserving Processes.

Although experiments in wood preserving now date back some centuries, and the list of substances experimented with seems nearly endless, * there are but few antiseptics which have stood the test of time, or have been worked commercially.

Special activity seems to have set in with the Railway Era, and the consequent demand for timber which had to be exposed to the weather.

Hundreds of patents were then taken out in England, and the committee has collected 104 issued in the United States. Few of them, however, have proved permanently successful.

Mr. W. P. Moir, in a paper read in 1869 before the Philosophical Society of Glasgow, gives the following list of the names of the patentees and the most valuable compounds employed :

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*In a treatise on the preservation of timber, by Wm. Chapman, Civil Engineer, published in London in 1817, will be found records of experiments with, and mode of application of, the following substances:

Sulphate of iron,	Arsenic,	Mineral coal,
Sulphate of copper,	Barytes,	Charcoal powder,
Nitrate of silver,	Salt,	Coal-tar oil,
Corrosive sublimate,	Quick-lime,	Vegetable oils,
Sulphate of zinc,	Alumine,	Fish oils,
Carbonate of soda,	Selenite,	Essential oils,
Caustic soda,	Soap,	Vapors of oil,
Charring,	Resin,	etc., etc., etc.,

which had been applied to the preservation of timber for ships, jetties, bridges, buildings, etc., etc. This, it will be seen, covers almost all the ground since traveled over by patentees, who are constantly even now experimenting with and patenting substances which had been investigated and discarded by Mr. Chapman and his predecessors.

Kyan............	1832	........Chloride of mercury.
Margary.........	1837	........Sulphate of copper.
Bethell..........	1838	........Creosote or pitch oil.
Bethell..........	1848	
Burnett	1838	........Chloride of zinc.
Burnett..........	1840	
Boucherie........	1839	........Pyrolignite of iron.
Boucherie........	1846	........Sulphate of copper.
Payne...........	1841	........Sulphate of iron.
Payne...........	1846	........Carbonate of soda.

Concerning the modes of application, Mr. Moir says :

"The methods employed practically in working these patents were three in number, namely : steeping, vital suction and pressing in close vessels ; Kyan and Margary employed the first mentioned method ; Boucherie employed the second, and Payne, Burnett and Bethell employed the third, which was also latterly adopted by Boucherie. The first and third methods required that the timber should be seasoned and free from sap."

These original patents have now all expired, and the use of the antiseptics which have proved most effective is open to the public. Whatever valuable patents have since been taken out refer chiefly to the modes of application, such as steaming in closed cylinders, to season the wood and remove the sap, and various devices to prevent the antiseptic from washing out upon exposure. Whether it will pay to use them each party will determine for himself, but it may be said in general terms that we now know the antiseptics which are most effective, and that the best modes of application are also pretty well known.

It will much simplify matters, for those who have not made a study of the subject, to group, so far as possible, the records of experience under the names of the best known processes, and to include therein various modifications which had sufficient of novelty to form the basis for a new patent. We have, therefore, classified the various experiments in the United States, concerning which we have been enabled to gather information, under the following heads :

1. Kyanizing—or use of corrosive sublimate.
2. Burnettizing—or use of chloride of zinc.
3. Creosoting—or use of creosote oil.
4. Boucherie—or use of sulphate of copper.
5. Miscellaneous—or use of various substances.

In referring to these experiments, we have endeavored to point out the causes of the success or the failure, and where full information seemed desirable, we give, in the appendix, the text of letters received by us over the names of their respective writers.

Many of these gentlemen took sufficient interest in the matter to hunt up and send to the committee specimens of the timber operated

upon in these experiments. These specimens were exhibited at the National Exposition of Railway Appliances, held in Chicago in June, 1883, and are now deposited in the museum of the Civil Engineers' Club of the University of Illinois, at Champaign, Illinois.

Kyanizing.

As already stated, Kyanizing was first introduced in 1832. It consists in steeping the timber in a solution of corrosive sublimate, probably the most powerful antiseptic known next to creosote.

The original proportions were one pound of the dry salt to four gallons of water, or a solution three per cent. strong by weight. Of this the timber absorbed six or seven pounds of salt per "load" of 50 cubic feet, or say ten to twelve pounds per 1 000 feet, board measure. As the price of this chemical was then $1.25 per pound, it cost some $12 or $14 per 1 000 feet, board measure, and this led to a more sparing use of it. Ultimately the solution was reduced to one pound to ten gallons, or even fifteen gallon of water (1.2 to 0.8 per cent. by weight), and with the latter the timber absorbed about two and a half pounds of the salt per 1 000 feet, board measure.

It was also applied by the "Boucherie" process, but the timber was found to absorb too much of the salt, and some of the solution necessarily ran to waste. The cost induced some of the contractors to further reduce the strength of the solution. To speak in plain terms, it led them to cheating, and Kyanizing fell into contempt in England. Moreover, the process is very tedious, because of the length of time required to impregnate the timber, and there are now but two private establishments in this country (which will be noticed further on) which Kyanize timber for their own use.

As this salt now costs fifty to sixty cents a pound, and as an absorption of four or five pounds per 1 000 feet, board measure, is considered sufficient, Kyanizing now costs about $6 per 1 000 feet, board measure. Where and when it will be profitable to use it will depend upon the price of the timber and its subsequent exposure, and in order to serve as a basis for forming conclusions on this subject we have compiled the table on page 253 of sixteen experiments, which have been made in this country, and we add the comments which they seem to require.

Comments on Kyanizing Experiments.

Concerning the first experiment in the list, General T. J. Cram says, in a report to the Chief of Engineers, made September 9th, 1870 :

"I have found our northern red cedar treated with the old Kyan process (an infusion of corrosive sublimate), after 22 years' exposure, lying on a slope of strong limy soil, to have gone to decay, especially the lower ends of the sticks, and Kyanized white oak of Michigan, rest-

RECORD OF SOME AMERICAN EXPERIMENTS.

KYANIZING,

Or use of a solution of chloride of mercury (corrosive sublimate).

No.	LOCALITY.	Year.	Process.	Material Treated.	Subsequent Exposure.	Results.	Authority.
1	Northern Central Railroad	1838	Steeping	Chestnut ties	Railroad track	Favorable to 1849	T. J. Cram.
2	Ft. Ontario, N. Y.	1839	"	Hemlock timber	Fortifications	Partial success	W. P. Judson.
3	Chesapeake and Ohio Railroad	1840	"	Oak ties	Railroad track	Favorable to 1854	H. D. Whitcomb.
4	Alexandria	1840	"	Timber	Bridge	Success to 1862	W. R. Hutton.
5	Delaware and Hudson Canal	1842	"	Rope	Inclined planes	Abandoned	J. Archbald.
6	Baltimore and Ohio Railroad	1842	"	Ties	Railroad track	Not encouraging	J. L. Randolph.
7	Old Colony Railroad	1845	"	"	"	Did not pay	I. Hinckley.
8	Eastern Massachusetts Railroad	1846	Pressure	"	"	Cost too much	H. Bissell.
9	Providence and Worcester Railroad	1847	Steeping	"	"	Did not pay	I. Hinckley.
10	Lowell Canal Company	1848	"	Timber	Bridges	Continued success.	J. B. Francis.
11	New York Central Railroad	1849	"	Ties	Railroad track	Favorable to 1859	J. F. Wilkinson.
12	Philadelphia and Reading Railroad	1850	"	Pine timber	Bridges	Success	J. D. Steele.
13	Fitchburg Railroad	1853	"	Joists	Shop floor	Failure	J. Adams.
14	Blackstone Bridge	1854	"	Pine timber	Bridge	Success	W. H. White.
15	Boston and Providence Railroad	1856	"	Ties	Railroad track	Unfavorable	G. F. Folsom.
16	Eastern Massachusetts Railroad	1881	"	"	"	Too recent	H. Bissell.

ing upon the same kind of dirt, dozed and rotted twenty years after the treatment.

"Chestnut railroad ties, grown upon the barrens of Maryland, Kyanized and laid upon a limy soil, some miles north of Baltimore, in 1838, I saw tested 11 years afterward, and then perfectly sound and more solid than when laid; while those of the same kind of wood, untreated but laid at the same time, in the same kind of soil and exposure with the treated ones, lasted only 7 years before they required renewal.

"This experiment of Kyanizing timber was the first, I believe, ever practiced in our country. Ties enough were treated for 1 mile of track, costing 12½ cents per cubic foot of timber. The process, however, was so unhealthy, salivating all the men, it had to be abandoned. It would be worth while to ascertain if those Kyanized ties are yet sound. At that time the untreated ties cost only 14 to 16 cents."

Diligent inquiries among the present officers and some of the former officials of the Northern Central Railroad have failed to elicit any further information as to the final result of this experiment. It is very evident, however, why it was not followed up. Cross-ties usually contain from 2 to 3½ cubic feet of timber, which, at 12½ cents per cubic foot, would make the cost of treatment, at that time, from 25 to 44 cents per tie. This is wholly out of proportion with their original cost, which was 14 to 16 cents apiece. The same ties would now cost untreated about 50 cents apiece, and at the reduced cost of corrosive sublimate could be Kyanized for 15 to 25 cents each.

The records of a similar experiment (No. 3) on the Louisa, now Chesapeake and Ohio Railroad, are furnished by Mr. H. D. Whitcomb. It appears to have been successful up to a certain time, and then to have been lost sight of, probably because the cost of preparation was more than that of the ties.

Experiment No. 2, that at Fort Ontario, has been fully described in the paper of Mr. W. P. Judson, published with our preliminary report. After thoroughly investigating the results, Mr. Judson came to the following conclusions:

"An examination of this work indicates that Kyanized hemlock (and probably Canada white pine also), if set up so that there should be a free circulation of air about it, away from contact with moist earth, and with its bases and joints so formed that water would not lodge in them, would be 80 per cent. sound after 40 years. The use of the process is not recommended for a work which will be liable to continuous moisture."

Mr. Judson, therefore, does not believe that Kyanizing would be satisfactory for railroad ties, in view of the moist nature of their exposure, and his view is confirmed by the results of the experiments on the Baltimore and Ohio Railroad (No. 6) in 1842, on the Old Colony Railroad (No. 7) in 1845, and on the Providence and Worcester (No. 9) in 1847, which were all abandoned as unprofitable.

Concerning experiment No. 15, on the Boston and Providence Railroad, in 1856, Mr. G. F. Folsom, Superintendent of Construction, writes: "The ties were green and half seasoned pine and spruce. After a few years' service the hearts of the ties were found decayed, while ¼ to ½ an inch of the surface was as sound as when laid under the track."

Concerning experiment No. 11, on the New York Central Railroad, Mr. J. F. Wilkinson, of Syracuse, N. Y., says: "In 1849 a quantity of hewed hemlock cross-ties were charged with the solution of corrosive sublimate, I think by immersion in vats prepared for this purpose. In some alterations that were made in the track of the road a large quantity of these ties were taken up after 4 years' use in the main track, and about 2 000 of them were laid in the branch tracks at Oriskany Station. In 1859 I examined the ties in these branches, and found that there was comparatively little decay among them. I do not remember how long it took to prepare these cross-ties. I think that at the time it was estimated to cost about 10 cents each. There were certainly several years added to the duration of the cross-tie."

Mr. J. B. Francis, Past President of this Society, gives Kyanizing preference over other processes; he has been working it with success since 1848 (experiment No. 10), and has furnished the committee the interesting account published in Appendix No. 2.

He informs us that he chiefly uses the timber Kyanized at Lowell for bridges over the canal, and that although he has repeatedly prepared experimental ties for the neighboring railroads, none of them, save the Eastern Railway of Massachusetts, have adopted the process.

For bridges, or for timber exposed to weather alone, and not to constant moisture, there seems to be no question as to the beneficial effects of Kyanizing. This is markedly shown by the record of experiment No. 4, on the Alexandria aqueduct, at Georgetown, D. C., where 9 spans of Burr truss bridge stood from 1840 to 1862, and failed even then, not from decay, but from defects in construction.

It is also shown by the record of experiment No. 14, at the Blackstone River bridge, on the New York and New England Railroad, which consisted of a Pratt truss, built and Kyanized in 1848, and which, although much overstrained by the increased weight of rolling stock, was found, when taken down in 1876, after 28 years of exposure, almost entirely undecayed. Even the foot of the posts, which rested upon oak blocks, were perfectly sound.

A like success attended the Kyanizing, on the Philadelphia and Reading Railrcad, of two bridges in 1850 (experiment No. 12), the timber of which remained sound for at least twenty years.

Where, however, timber is exposed to moisture, Kyanizing is of doubtful utility. On the Fitchburg Railroad in 1853 (experiment No. 13), the floor timbers for an engine house at Charlestown were Kyanized, "because the location was very damp." They were found, however, a few

years afterward as much decayed as if they had not been so prepared.

This experience is confirmed by the appearance of a number of Kyanized spruce planks, laid in gate boxes on the Lowell water works, and kindly taken up to send to the committee by Mr. Geo. E. Evans, City Engineer. Where these planks were in dry places, they are quite sound after twelve years' exposure, and the life of the wood has been at least doubled. Where they were in wet places, they are decayed, and the amount of decay seems to be in proportion to the dampness of the situation.

From the foregoing, it seems pretty evident, that for bridges, trestles, fences and similar exposures, Kyanizing is a good process to use, and may safely be relied upon to preserve the wood twenty to thirty years, but that for cross-ties, pavements and work exposed to constant moisture, success is more doubtful, probably in consequence of the washing out of the corrosive sublimate.

There are now two establishments for Kyanizing in the United States. That at Lowell has been referred to in the letter of Mr. J. B. Francis. It consists of two pits or tanks, built of masonry, and lined with wood, each 49 feet long, 7 feet 4 inches wide and 4 feet deep, capable of holding 10 000 feet, b. m., of timber. The sticks are handled in and out by cranes, which also serve to swing large stones that are placed on the wood to prevent it from floating up. It is allowed to steep one day for each inch in thickness of its least dimension, and one or two days in addition. The solution used contains 1 per cent. by weight of corrosive sublimate, and from 4 to 5 pounds of this are absorbed per 1 000 feet, b. m. At a cost of 53 cents a pound, this comes to $2.12 to $2.65 per M., b. m., for chemicals, and as the labor costs about as much more, the total cost may be said to be $5.00 to $6.00 per 1 000 feet, b. m., exclusive of interest on plant and on timber in process of preservation. Some work is done for outside parties, for which $7 per 1 000 is charged, this being supposed to cover a small profit, enough to pay interest on the plant.

The other establishment is on the Eastern Railroad, at Portsmouth, N. H., and an account of this, together with a description of experiments Nos. 8 and 16, will be found in the letter of Mr. H. Bissell, Engineer of Maintenance of Way, in Appendix No. 3.

From this it will be seen that the Eastern Railroad, having resorted to Kyanizing in 1846, by the unusual process of forcing the solution into the wood, in a closed cylinder, subsequently abandoned it, but has taken it up again for the preparation of its ties by the steeping process.

Too short a time has elapsed since 1881 to judge of the results, but the data gathered by your committee indicate that where these ties are laid in dry places (on stone ballast for instance), their life will be materially increased. Where they are laid in wet places, it is doubtful whether the benefit will be commensurate with the cost.

Burnettizing.

The original mode of application employed in Burnettizing was by steeping the timber in a solution of chloride of zinc, in the proportion of 1 pound to every 4 gallons of water. This was found exceedingly tedious, and somewhat ineffective, and Sir Joseph Burnett subsequently adopted Bethell's process (as applied to creosote), of placing the timber in a closed iron cylinder, forming a partial vacuum, to extract the sap, air and water, as far as practicable, and then forcing in the preserving liquid under pressure. This process has since been improved by using steam in the preparatory stage in the cylinder, in order the better to open the pores of the wood to receive the antiseptic, as well as by several devices which will hereafter be described, to prevent the chloride of zinc, which is a very deliquescent salt, from washing out when exposed to moisture.

It is probable that some of the failures which will be described are attributable to the early imperfections in Bethell's mode of application.

On page 258 is a table of the experiments of which the Committee has been able to obtain record.

Comments on Burnettizing.

Burnettizing seems to have been first introduced in this country at Lowell, Mass., in 1850, as stated in the letter of Mr. Francis (Appendix No. 2). It was there worked by the Bethell process till about 1862, when it was abandoned to return to Kyanizing, the latter being thought more effective for bridge and building timber.

In 1855 the Union (horse) Railroad of Cambridge, Mass., was laid with spruce stringers and sleepers, Burnettized at Bangor, Me. The stringers are now (1883) all worn out, but Mr. K. C. Chaffee, the President, writes that "many, and I think the majority, of the sleepers are in good condition to-day," that is to say, after 28 years' exposure.

The experiment seems to have been given up because subsequent lots prepared by contract turned out badly. Mr. Chaffee writes:

"I became satisfied that it could not be got well done (by the contractors). It is of no benefit unless done while the timber is perfectly green, and then well done."

Indeed it may be said once for all that success in timber preservation, by whatever method, depends upon the thoroughness with which the work is done, and that no economy is so false as that which seeks to scrimp the legitimate cost.

In 1856 (experiment No. 3) the Vermont Central R. R. erected Burnettizing works, and prepared large quantities of timber and ties. Some of the latter were found to be nearly sound in 1880, as stated in the letter of Mr. J. W. Hobart, General Superintendent, given herewith in Appendix No. 4.

RECORD OF SOME AMERICAN EXPERIMENTS.

BURNETTIZING,

Impregnating with Chloride of Zinc under Pressure.

No.	LOCALITY.	Year.	Process.	Material Treated.	Subsequent Exposure.	Results.	Authority.
1	Lowell Canal Company	1850	Bethell	Various	Canal work	Unfavorable	J. B. Francis.
2	Cambridge Railroad	1855	"	Spruce ties	Railroad track	Favorable	K S. Chaffee.
3	Vermont Central Railroad	1856	"	Hemlock ties.	"	Success, 1882	J. W. Hobart.
4	Boston Wharf	1857	"	Spruce plank	Wharf	Sound to 1872	C. Page & Co.
5	Middlesex Railroad	1857	"	Spruce stringers	Horse railroad	" "	C. W. Palmer.
6	South Boston Railroad	1857	"	"	"	" "	R. Johnson.
7	Boston and Albany Railroad	1860	"	Spruce ties	Bridge floor	Favorable	E. S. Philbrick.
8	Chicago, Rock Island and Pacific Railroad	1860	"	Timber	Howe truss	Success, 1882	Hugh Riddle.
9	Erie Railway	1861	"	"	Bridges	Unfavorable	W. B. Coffin.
10	Ohio and Mississippi Railroad	1862	"	"	"	Doubtful	T. S. Sedgwick.
11	Philadelphia, Wilmington and Delaware R. R.	1863	"	Ties	Railroad track	Abandoned	I. Hinckley.
12	Chicago, Rock Island and Pacific Railroad	1866	"	"	"	Success	M Alexander.
13	Havre de Grace	1866	"	Timber	Bridge	Strength injured	E Larkin.
14	Philadelphia and Reading Railroad	1867	"	Ties	Railroad track	Hard and brittle	W. Lorenz.
15	Lehigh and Susquehanna Railroad	1867	"	"	"	Success, 1882	L. L. Buck.
16	Union Pacific Railroad	1868	"	Cottonwood	"	Abandoned	L. S. Bent.
17	Long Island Railroad	1868	"	Stringers	Pile bridge	Failure	F. S. Gannon.
18	Philadelphia	1868	"	"	Horse railroad	Unknown	G. S. Gandy.
19	Washington	1872	"	Spruce	Pavement	Failure	J. A. Partridge.
20	"	1872	"	"	Laboratory	Zinc washed out	W. C. Tilden.
21	St. Louis Bridge	1879	Wellhouse	Gum blocks.	Pavement	Favorable, 1883	C. S. Smith.
22	"	1879	"	Pine stringers	Bridges	" "	"
23	St. Louis, Iron Mountain and Southern R. R.	1879	"	Ties	Railroad track	" "	H. Constable.
24	Illinois and St. Louis Railroad	1880	"	"	"	" "	C. H. Sharman.
25	Atchison, Topeka and Santa Fé Railroad	1881	"	"	"	" "	A. A. Robinson.
26	St. Louis	1879	"	Gum blocks	Pavements	" "	H. Constable.
27	Norfolk, Va	1880	Thilmany	Pine piles	Teredo	Failure	P. C. Asserson.
28	Chicago and Alton Railroad	1880	"	Ties	Railroad track	Too recent	W. F. Merrill.
29	Erie Railway	1882	"	"	"	"	O. Chanute.
30	St. Louis	1883	Zinc gypsum	"	"	"	T. Plate.

The process seems to have been given up after four years' use, in consequence of the delays and annoyances involved in treating such large quantities of timber as are used on a railroad, only to find out after a lapse of 25 years what a great success it had been.

Experiments Nos. 4, 5 and 6 show that some spruce plank and track stringers, Burnettized in 1857, and laid on a wharf in Boston, and on some horse railroad, were yet sound when examined in 1872, or some 15 years afterward. We have not been able to trace their subsequent history.

In 1860 (experiment No. 8) the Chicago, Rock Island and Pacific R. R. built a Howe truss bridge of 8 spans of 150 feet each, which was still in use and in fair condition in 1882, as stated in the letter of Mr. Hugh Riddle, its President, published in our Preliminary Report.

In 1860 some Burnettized spruce ties were placed in the floor of an iron bridge built by the Boston and Albany R. R., in the City of Boston. They lasted 9 years, and were replaced by untreated white pine, which only lasted 5 or 6 years, when chestnut ties, unprepared, were substituted, which have lasted seven years, and were replaced last season by a second set of chestnut ties, also unprepared.

A full account of this experiment (No. 7) will be found in the letter or Mr. E. S. Philbrick, published herewith as Appendix No. 5.

It will be noticed therefrom that the Burnettizing doubled the life of the spruce, which would otherwise have lasted but 4 or 5 years, and that the ties finally failed by checking and splitting, so as no longer to hold the spikes. Exposure as bridge ties seems particularly liable to bring about this result, and Mr. Philbrick's experience leads him to believe that Burnettizing is of more avail where timber is covered with earth than when fully exposed to sun and air. This opinion is confirmed by the statement of Mr. Hobart (Appendix No. 4), who found Burnettized ties nearly sound after having laid some 25 years in an old side track, nearly covered with earth and grass, and this probably results from the less opportunity for the washing out of the chloride of zinc from the timber by the action of rains.

In 1861 (Experiment No. 9) the Erie Railway built a set of Burnettizing works at its bridge shop at Owego, New York. These works chiefly consisted of an iron cylinder 70 feet long and 6 feet in diameter, with a heavy iron door at each end, and a track running through it, on which the material was run in on small trucks, moved by a hand-power windlass. The capacity was 13 000 feet, b. m., and the Bethell process was used.

When the cylinder was filled and the rubber-packed doors closed, a powerful air-pump was applied, and as perfect a vacuum formed as possible, and maintained one hour, to withdraw the sap and air from the timber. A stop-cock was then opened in the pipe connecting the cylinder with the tank containing diluted chloride of zinc, and the liquor

admitted. When the cylinder was filled, the stop-cock was closed, and a powerful force-pump set at work, which forced the solution into the cylinder under a pressure of 120 to 150 pounds per square inch. This pressure was maintained about four hours, and left sometimes in over night, when the timber was taken out.

The strength of the solution was about 2 or 3 per cent., and with labor at $1.50 per day, the cost of the treatment is said to have been from $1.50 to $2.50 per 1 000 feet, b. m.

The treatment was applied almost entirely to bridge timber and plank for platforms, crossings, etc. Very few cross-ties were prepared, and only as an experiment.

The results were not entirely satisfactory, and when the works burned down in 1869 they were not rebuilt. Two-inch plank seemed to be well preserved, but large timber, taken out of bridges 8 or 9 years after treatment, showed a hard crust from ¼ to 1 inch thick all round, but was rotten at the center, thus tending to deceive the bridge inspectors as to the soundness of bridges which might really be insecure.

Some pains have been taken to ascertain the causes of this want of success. They seem to have been as follows:

1. Original imperfections in the "Bethell" process. The partial vacuum did not properly clear the timber of sap. This has since been improved upon by previously steaming the timber, to liquefy and vaporize the sap, before the vacuum is applied.

2. It was probably a mistake to select bridge timber for this experiment; imperfectly as the work was done, it would have proved a far greater success if it had been applied to cross-ties.

3. Operating upon unseasoned timber. As practiced in Europe, Burnettizing is exclusively applied to seasoned timber. This being generally imported from a distance, has a chance to dry in transit; or if cut in the vicinity of the works, it is piled up for several months before treatment, or is thoroughly steamed, so that the water may evaporate and make room for the solution. Moreover, it is also well dried before using, to prevent the zinc from washing out. As a confirmation of this view, it may be mentioned that while the bridge timber did not last well, several sets of switch ties which had been cut about 8 months, and seasoned, were Burnettized at Owego, for the road department of the Erie Railway, and laid in its tracks, with the result that nine years afterward they did not show a particle of decay. These ties have been lost sight of since, but your committee has in its possession an oak tie, one of a lot of two car loads, seasoned and Burnettized at Owego, which lay in the track at Susquehanna station for 17 years, and is almost perfectly sound to-day.

4. Insufficient pressure. It has been suggested that the pressure ought to have been some 200 pounds per square inch, and continued 8

hours instead of 4. This might have produced somewhat better results, but it is believed that the last cause, which remains to be mentioned, more fully accounts for the partial want of success.

5. Undue haste in the treatment. In accordance with the usual railroad practice of never ordering materials until they are imperatively required, the timber was not procured until the bridge which it was intended to rebuild was about ready to come down. Then there was great haste; the Burnettizing works were hurried up, and the timber went straight from the stump into the cylinder, and from that into the bridge, with very imperfect treatment. The pressure was applied to the operatives, instead of to the cylinder, and as a result the timber was "put through," without sufficient preparation, some of it hard frozen in winter.

Mr. Jas. D. Bishop, formerly Superintendent of Bridges of the Erie Railway, who had charge of these Burnettizing works, writes: "All the timber used in renewals of bridges, and exposed parts of buildings, platforms, etc., upon the road, which was a very large amount, was hurried through this process, and for the want of time was done quite imperfectly. I consider the process of Burnettizing timber a success, in preserving the same to at least 50 per cent. beyond its natural life, if the Burnettizing is well done."

Mr. H. D. V. Pratt, formerly General Superintendent of the Erie Railway, writes:

"The timber used in bridges, that was Burnettized in the winter, was full of frost, and Burnettizing had no other effect than to confine the sap, and make the timber decay much sooner than it otherwise would have done."

Under these circumstances, it seems to be no wonder that the results were not entirely satisfactory, but all this amounts to saying a very simple and very obvious thing—that we cannot hope to get a preservative solution into the timber unless we first contrive to make a place for it, and that in order to be successful, the work must be done skillfully and thoroughly.

For this there must be no undue haste; but at the same time it must be acknowledged that the delays required properly to season and to prepare timber and ties are particularly exasperating to railroad men, and many of the works and experiments which have heretofore been abandoned have doubtless been given up because of the delays which they brought about in necessary renewals of bridges and of roadway.

The above information has been furnished in large part by Mr. W. B. Coffin, Superintendent of the western division of the Erie Railway, and it should be stated in fairness that Mr. J. D. Bishop (who had charge of the works, and to whom this statement of the experiment has been submitted) writes that we "have put it rather too strongly as to its not being a success."

Now that the Bethell process has been improved by a preliminary steaming to season the timber, there seems to be no reason to doubt that the work can be well done at all seasons.

We may here refer to experiment No. 16, on the Union Pacific R. R. Burnettizing works were erected at Omaha by that company in 1867–8, and run about one year on cottonwood ties. The cost of treatment is stated to have been about 30 cents a tie.

The works were abandoned as impracticable, as not one-tenth of the ties used could be put through the machine. Some difficulty was also found from the brittleness of the prepared ties, probably, as will be explained hereafter, from the use of too strong a solution in order to hasten the process.

It is doubted by your committee whether it is wise to attempt to prepare artificially (by any process) ties for a road in process of rapid construction. The quantities required are too vast, and delays are too annoying. It is clear that if it is desired to lay some 3 miles of track a day, requiring about 8 000 ties, works consisting of one or two cylinders, the capacity of which are from 500 to 1 000 ties a day, will not be sufficient. The remedy is to provide an adequate plant, but this would be costly.

This difficulty disappears for roads in process of operation, and then it becomes quite practicable with one set of works to prepare the ties needed for renewals within a certain district.

Experiment No. 11, on the Philadelphia, Wilmington and Baltimore R. R., and experiment No. 14, on the Philadelphia and Reading R. R., are instructive, and at first puzzled your committee not a little. These companies set up their own works and Burnettized their own ties in order to have the work well done, and they overdid it.

They found the ties would last against decay, but that they broke in the track. As Mr. I. Hinckley, the President of the P., W. and B. R. R. expresses it, "they were as brittle as a carrot," and would break in unloading from a car. As Mr. Lorenz, the Chief Engineer of the Philadelphia and Reading R. R. puts it, "the elasticity and strength of the wood was destroyed. The ties became too solid for good wear of the rails," and many of them were removed from the track and used as fence posts, where they lasted a long time.

The explanation is that the solution was too strong, and the surplus zinc probably crystallized in the sap ducts of the timber, burst some of them asunder, and so made the wood brittle. On the P., W. and B. R. R., a saturated solution was used, probably 5 or 6 per cent. strong, and on the Philadelphia and Reading R. R. the solution was 3¾ per cent. strong, while experience in Germany has thoroughly established the fact that for railroad ties the solution should not be over 2 per cent. strong, and 1.91 per cent. is considered the standard.

In this connection we refer you to Appendix No. 6, which consists of

an account of German experience with preserved railroad ties, written by Privy Councillor Funk, of the Cologne and Minden R. R., and translated for the "Railroad Gazette" of May 28, 1880. It will be found very interesting and instructive, and we may here quote the two conclusions which seem most important to us.

"No. 2. The average life of ties properly impregnated with creosote or chloride of zinc, under a powerful pressure, reaches:

For oak ties	19. 5	years.
" fir " (hemlock?)	14 to 16	"
" pine "	8 " 10	"
" beech "	15 " 18	"

"No. 7. The results of impregnation with chloride of zinc and creosote are about equal. But as the impregnation with creosote costs about three times as much as with chloride of zinc, a majority of the German railroads have gone over to the latter."

Experiment No. 12, on the Chicago, Rock Island and Pacific, in 1866, confirms the German experience. About 75 per cent. of Burnettized hemlock ties were still in the track in 1882, after 16 years of exposure, as stated in the letter of Mr. M. Alexander, roadmaster, given as appendix No. 7.

A similar result was obtained in experiment No. 15, on the Lehigh and Susquehanna R. R., where Mr. L. L. Buck, whose letter is given in Appendix No. 8, found that maple, beech and hemlock ties had resisted decay almost perfectly with 15 or 16 years' exposure.

Concerning experiments Nos. 10, 17, 18 and 19, we have been able to obtain but little information. They seem to have been failures, but whether due to bad work or to the exposure we could not find out.

We may say, however, that we consider Burnettizing less well adapted to bridge work than to the preservation of ties. This is indicated by the results of experiment No. 13, at the Havre de Grace bridge, where pine timber Burnettized proved brittle. Mr. Edward Larkin, who had charge of this bridge, and whose letter we give in Appendix No. 9, states that the solution was $1\frac{12}{100}$ per cent. strong. We are inclined to believe that it must frequently have been exceeded in working, as a solution of this strength has nowhere else (that we know of) proved injurious to the strength of the timber.

It has been found, however, both in this country and in Europe, that when zinc solutions are employed, weak enough not to injure the strength of the timber, they are likely to wash out under the action of rains and moisture, and to leave the timber unprotected. This is quite well shown by the ties on the Chicago, Rock Island and Pacific Railroad (experiment No. 8), which are decayed and exfoliated on the outside.

Burnettized ties decay from the outside toward the heart, while creosoted ties are more likely to decay from the heart outward. The

reason is the same in both cases, decay beginning at the point where there remains the least of the antiseptic material. The heart-wood being most dense, naturally absorbs the least; but in the case of Burnettizing, the chloride of zinc being a very deliquescent salt, readily washes out and allows decay to set in. Creosote or dead oil does not work out, and, in time, decay begins in the heart-wood which has received the least of it.

When wooden pavements began to be largely used in Washington, D. C. (experiment No. 19, which, by the way, seems to have failed because of very bad work), Mr. W. C. Tilden, A. A. Surgeon, U. S. A., made some chemical tests on the various processes of wood preserving which were used or proposed. In the case of Burnettized spruce (experiment No. 20), he found that all the zinc was easily removed by acidulated water, and this defect in Burnettizing seems to be so generally understood that it has led to the patenting of a number of devices to remedy it.

The first of these in point of date is that of Mr. W. Thilmany, who patented the use of a double solution, the first being that of sulphate of zinc, and the second, subsequently applied, a solution of chloride of barium, which, it is claimed, by combination with the first solution, changes it into an insoluble salt of sulphate of baryta. Experiments Nos. 27, 28 and 29 pertain to this process, and time will have to determine whether they prove successful. Chemists who have been consulted by your committee doubt whether it is possible for this chemical reaction to take place on the inside of the sap-ducts of the wood, many of which are only 1-200 of an inch in diameter.

The next patented process was that of Mr. Wellhouse, who also employs a double solution, the first being chloride of zinc, to which a little glue is added, and the second a solution of tannin, which it is claimed forms, upon coming into contact with the glue, small pellicles or films of insoluble artificial leather, which plug up the mouths of the sap-ducts, so as to prevent the zinc from washing out. Experiments Nos. 21, 22, 23, 24, 25 and 26 pertain to this process, and the results seem thus far to be favorable.

The last patented process which seems to call for mention is that of Mr. Hagen, who uses but one solution consisting of chloride of zinc and gypsum. It is claimed that the gypsum (sulphate of lime) crystallizes and hardens inside of the sap-ducts, and thus forms partitions to hold the chloride of zinc within the cells. Experiment No. 30 represents this method, and the process is now on its trial.

There are now three Burnettizing works in this country. One at Defiance, O., operates the Thilmany process. An account of the latter is given in Appendix No. 10, by Mr. O. Thilmany, the proprietor.

Works at St. Louis operate the Wellhouse process, of which an account is given in Appendix No. 11, by Mr. J. P. Card, President,

while still other works at St. Louis are operating the zinc-gypsum process, of which an account is given in Appendix No. 12, by Mr. Theo. Plate, President.

The cost of Burnettizing, when well done, is about five dollars per 1,000 feet, b. m., or twenty to twenty-five cents a tie. It is particularly adapted to the latter purpose, and your committee recommend it as the available process to use (in view of the cost) for the preservation of railroad ties. It is believed to be less well adapted to bridge or trestle work, but for wooden pavements, if well done, it will probably prove a success.

It cannot be too strongly insisted upon that the work must be well done. The sap or moisture must be removed from the wood to make sufficient room for the antiseptic, and a sufficient amount of the latter must be put in. To do this thoroughly, of course, costs more than to do it hurriedly and badly. It will be noticed in Appendix No. 6 that the cost of Burnettizing has ranged from 5.8 to 19.2 cents a tie in Germany. It has been done for 15 cents a tie in this country, but is said to have cost about 25 cents a tie on the P., W. & B. R. R., and some 35 cents a tie on the Philadelphia and Reading Railroad, where, however, there was an unusual amount of handling.

Creosoting.

This process consists in injecting the timber with hot creosote oil in a closed cylinder under pressure. It was invented and brought into use in 1838 by Mr. John Bethell, of England; and in 1853, in a discussion of a paper (by Mr. H. P. Burt) before the British Institution of Civil Engineers, he made the following among other remarks:

"Experiment proved that oil of tar, or creosote, was perhaps the most powerful coagulator of the albumen (of wood), while it, at the same time, furnished a water-proof covering for the fiber, and its antiseptic properties prevented putrefaction. If, then, the operation of injection was well performed, there was every reason to anticipate the perfect success of the system. He found that by forcing at least 7 pounds of creosote oil into each cubic foot of timber the process was perfect for railway work, but for marine work it was better not to have less than 10 pounds per cubic foot.

"He was inclined to prefer the employment of porous timber, as it absorbed the creosote more readily, was more perfectly saturated, was cheaper in first cost, and, when properly prepared, would last longer than heart of oak or any other very solid timber." * * * * *

"The best timber for use was young, growing wood, *thoroughly dried;* if it was fresh cut, or had been floated so as to saturate the pores with water, there was great difficulty in creosoting it." * * * * *

"He had experienced so much difficulty in procuring a proper qual-

ity of oil of tar that he was compelled to establish manufactories and to distil it to suit his own purposes."

The best known engineers, such as Messrs. Brunel, Hawkshaw, Rendell and others, also gave, on that occasion, the results of their experience, which was in every case satisfactory when the work was thoroughly done, and creosoting has now become the standard mode of timber preparation in England.

There is no question about its efficacy and economy when well done, as evidenced by the fact that out of 12 of the leading railways of Great Britain to whom Mr. Bogart, Secretary of this Society, addressed circulars of inquiry in 1878, 10 used creosoted sleepers, and some of them forwarded with their answers sleepers taken from their tracks, which were yet sound and in use after 22 years of exposure.

As a protection against marine worms (the *Teredo Navalis* and *Limnoria Terebrans*) creosote is the only known preservative, and if there be enough of it injected it is thoroughly efficient. All other substances which have been tried have failed, but the success of creosote has been established by abundant evidence all the world over.

The English have found 10 or 12 pounds to the cubic foot sufficient in their harbors. The Dutch and Belgian engineers use about the same. But the French, relying upon a series of very careful experiments, extending over a series of years, made by Mr. A. Forestier, consider that about 19 pounds to the cubic foot is required in their harbors in order to be quite safe against the *teredo*. This latter quantity has been used in this country by Mr. J. W. Putnam for piles exposed along the Gulf of Mexico, and it seems probable that the higher temperature of the sea water, and consequent greater activity of the *teredo* in the French and our own southern harbors, requires a more thorough impregnation with creosote than in northerly waters to afford immunity.

The conditions under which creosoting is done in England differ from those in this country in two important particulars:

1. The English operate upon *seasoned* timber, which, as it is chiefly brought from the islands of the Baltic, from Norway and from Sweden, generally reaches them some 5 or 6 months after it is cut, and frequently remains stacked up some months more after arrival before it is creosoted. All the English engineers specify that "the timber shall be thoroughly dry before being creosoted," while in this country we have almost invariably operated upon freshly cut timber, full of moisture and sap.

This has led to steaming the timber previous to its injection with creosote (as well as with the metallic salts), in order to vaporize the moisture and make room for the solution. There are several methods of effecting this steaming, covered by a number of patents more or less meritorious, but the committee has included them under the general head of steaming in describing some American experiments.

It is understood that steaming is now also used abroad, particularly

in Germany, even when seasoned timber is injected, it being considered a valuable improvement upon the original process of Mr. Bethell.

2. Creosote is cheap and abundant in England, while it is comparatively scarce and dear in this country. This, together with the higher price of labor and the longer time required to operate upon freshly cut timber, has made creosoting so much more expensive here than in England that in a majority of cases calculation showed that it was cheaper to let the timber rot and to replace it than to go to the expense of preparing it against decay.

This condition of affairs brought about a considerable number of inventions and experiments to circumvent the foreign experience and to make a little creosote perform as much as a great deal. None of these can be said to have been successful, and it is one of the anomalies which at first much puzzled your committee that the record of creosoting experience in this country should chiefly consist of failures, while the process is a thorough success in England.

Investigation showed, however, that most of these experiments were not true creosoting, as understood abroad, and, inasmuch as failures are far more instructive than successes, they are here given, under the general head of "Creosoting," while our comments will show wherein they differ from true creosoting.

Comments on Creosoting Experiments.

The first experiment upon the list, that on the Philadelphia and Reading Railroad in 1854, was not made with creosote at all, but with the coal tar from which it is extracted. "Some 70 000 ties were prepared by first placing them in a large drying chamber for 76 hours, at a temperature of 120 degrees, then placing them for 2 hours in a bath of coal tar, at a temperature of 150 degrees." Subsequently this was changed to the dipping of 2 feet at each end of the tie into the tar, so as to give the center a chance to part with any remaining moisture.

The cost was 8 cents a tie, but it was discontinued, because it was not found to prolong their life.

The Committee has heard, in a somewhat vague way, of a good many other experiments with coal tar. None of them proved successful, except where seasoned fence posts or paving blocks had their lower ends dipped. This kept out the ground moisture, while the wood could still dry out through the top. Whenever the whole stick was covered with coal tar, and the sap and moisture confined, the result was fermentation and failure, especially in those cases when the ammonia was not previously removed from the tar by boiling.

The second experiment (in 1865) was true creosoting. It was conducted under the instructions of Isaac Hinckley, Esq., then of Massachusetts, in the preparation of about 700 piles for the construction of a bridge over the Taunton River, on the Old Colony Railroad. Creo-

RECORD OF AMERICAN EXPERIENCE—CREOSOTING.

No.	Locality.	Year.	Process.	Material Treated.	Subsequent Exposure.	Results.	Authority.
1	Philadelphia and Reading Railroad	1854	Coal tar	Ties	Railroad track	Failure	W. Lorenz.
2	Taunton, Mass	1865	Bethell	Piles	Teredo	Favorable	I. Hinckley.
3	Callowhill Bridge	1868	Boiling	Plank	Bridge floor	Failure	R. Hering.
4	Chicago, Burlington and Quincy R. R.	"	Seely	Ties	Railroad track	Failure	T. H. Perry.
5	Chicago, Rock Island and Pacific R. R.	"	"	"	"	Failure	E. H. Johnson.
6	St. Clair Flats	"	"	Pine timber	Canal	Failure	F. Harwood.
7	Wilmington, Cal	1871	Robbins	Piles	Teredo	Failure	C. B. Sears.
8	Washington	1872	"	Paving blocks	Laboratory	Unfavorable	W. C. Tilden.
9	"	"	Seely	"	"	Favorable	"
10	Pittsburgh	"	"	"	Street	"	A. Dempster.
11	Washington	"	Constant & Smith	"	Laboratory	Unfavorable	W. C. Tilden.
12	"	"	Detwiler	"	"	"	"
13	"	"	Thomas	"	"	"	"
14	New Orleans	"	Boiling	"	Paving	Success	T. Forstall.
15	East River Bridge	"	Steaming	Plank	Caisson	Success	F. Collingwood
16	Boston	"	"	"	Floor	Success	Blake Mfg. Co.
17	Cleveland	1873	Seely	Blocks	Paving	Favorable	H. G. Wilson.
18	U. S. S. Vandalia	"	Steaming	Timber	Ship	Favorable	F. L. Fernald
19	Dry Tortugas	"	"	Gun platforms	Fortification	Failure	W. H. Hener.
20	Titusville	"	Petroleum	Ties	Railroad track	Various	O. Chanute
21	Rochester	"	"	Machines	Weather	Favorable	J. M. Harris.
22	Galveston	1874	Steaming	Pine blocks	Paving	Failure	G. M. Hartwick.
23	"	"	"	"	Stable	Success	W. E. Gregory.
24	"	1875	"	Piles	Teredo	Partial success	B. M. Temple.
25	New Orleans and Mobile R. R.	1876	"	"	"	Success	J. W. Putnam.
26	" "	"	"	Timber	Bridges	"	"
27	Bound Brook Railroad	"	Hayford	Ties	Railroad track	"	E. R. Andrews.
28	New York	"	Webb's	"	"	Failure	
29	Delaware Bay	1878	Steaming	Pine blocks	Teredo	Success	W. Ludlow.
30	Philadelphia and Reading Railroad	"	"	Ties	Railroad track	Success, 1882	W. Lorenz.
31	Boston	"	"	Fence posts	In earth	Favorable	A. F. Perkins.
32	Hoboken	"	"	Ties	Railroad track	"	W. W. Shippen.
33	"	1879	"	Piles	Teredo	"	"
34	Trenton	"	"	Planks	Bridge	Favorable	R. E. Pettit.
35	New Orleans	1880	"	Ties	Railroad track	"	T. Forstall.
36	Houston	"	"	"	"	"	M. G. Howe.
37	New Orleans	1882	"	Piles	Bridge	"	G. Bouscaren.
38	Charleston, S. C.	"	"	"	Wharf	"	J. W. Putnam.
39	Pensacola and Atlantic R. R.	"	"	" and timber	Bridges	"	"

soting works were erected for the purpose of treating these piles, and these works are still in use at Somerset, Mass. In 1878 the Chief Engineer of the Old Colony Railroad, the late E. N. Winslow, wrote as follows about these piles :

"We have removed about 200 of the 700. * * * The work was generally done with a rush and in a careless manner; many of the piles were fitted, knots trimmed up, etc., after they were creosoted. I find they are eaten in patches and spots, commencing apparently where the trimming was done. Upon examination I find the outer portion of the piles from ¼ to ½ inch in thickness, filled with creosote, to-day as limpid and odorous as when applied. Hence, I infer the attack has been made in almost every instance where the trimming or fitting was done."

The experiment was considered a success, and has been continued, but all trimming of timber after treatment, destined to be exposed to sea water, is now recognized, both here and abroad, as fatal to success, inasmuch as the *teredo* will attack any point unprotected by sufficient creosote, and will speedily make his way to the heart wood, which, in consequence of its density, can absorb but a small portion of this preservative.

The third experiment was simply an instance "how not to do it." Instead of being properly creosoted, the planks for the Callowhill bridge floor, in Philadelphia, were simply dipped into hot creosote, absorbed but a small portion of it, and decayed quite as fast as if they had not been treated at all.

Even the framing of creosoted timber which is to be exposed to sun, air and rain, is considered undesirable, as the cutting away of the saturated part admits the germs of decay to the less impregnated parts.

Experiments 4, 5 and 6 pertain to the Seely process, which was hailed at first as a great improvement over the methods pursued in the "effete countries of Europe."

The process consisted in immersing the wood in a closed iron tank of the oil, and raising the temperature to between 212 and 300° F. This was supposed to drive all the moisture out of the wood, when the hot oil was suddenly replaced by a bath of cold oil, which, condensing the steam remaining in the sap cells, was supposed to rush in and saturate the timber thoroughly.

It was believed to be well adapted to operating upon green, wet or unseasoned timber, and as the wood generally absorbed but 2 to 4 pounds of creosote to the cubic foot, it could be treated at about European prices. The process was vigorously pushed for a time, and introduced in all parts of the country. It failed on the Chicago, Burlington and Quincy Railroad (No. 4), on the Chicago, Rock Island and Pacific (No. 5), and on the Government works at the St. Clair Flats (No. 6).

It was possible, however, with sufficient time and expense, to obtain with this process better results than the above. A specimen paving

block (experiment No. 9), submitted to the Government chemist, Mr. W. C. Tilden, in 1872, presented a satisfactory appearance of saturation, and paving blocks in Pittsburg (experiment No. 10), as well as in Cleveland (experiment No. 13), having been saturated with about 4 pounds of creosote to the cubic foot, have lasted about 10 years, or some 4 or 5 years longer than they would have lasted in their natural state.

There were those, however, who believed that the Seely process used too much creosote, and who reasoned that if dead oil were applied to the timber in the shape of vapor, it would be much more penetrating, and a much smaller quantity would answer.

A number of devices were accordingly patented for smoking wood with the vapors of coal tar and of creosote. Of these, the process which became the best known was that of Mr. L. S. Robbins, which was first introduced in 1867.

It was most extensively advertised. Local companies were formed in New York, New Jersey, Pennsylvania, Massachusetts, New Hampshire, Connecticut and California, with millions of capital. A convention of delegates from each of these companies was held at the Astor House, in New York, in 1869, at which Mr. Robbins was spoken of as a "great public benefactor," whose "American genius has made an invention which may be classed among the greatest achievements in the useful arts, whose process accomplishes by the subtle agency of vapor, in a perfect manner, what the Bethell process, by the gross material, imperfectly did. The Bethell process, however, established the efficacy of coal tar treatment to preserve wood from decay, but how much more certainly will decay be prevented by the Robbins process ?"

The first record we have of the results is that of experiment No. 7, in the Government harbor works, at Wilmington, Cal., in 1871. Over a million feet of timber was treated by the Robbins process, being impregnated with about 1¾ pounds of oil to the cubic foot, at a cost of $10 coin per 1 000 feet, b. m. The engineer in charge, Mr. C. B. Sears, says:

"It utterly failed to protect the timber from the worms, which were not more than two months longer in attacking it than in attacking the untreated timber, and when once in, their action seemed to be more rapid and destructive than in the latter; in fact they relished it rather more."

But if the Robbins process was held in contempt by the *teredo navalis*, it was claimed that it was efficacious in preserving against decay "wooden pavements, railroad ties, telegraph poles, freight cars and coffins." It was examined for the first of these purposes (experiment No. 8), by Mr. Tilden, who reported:

"Absorption power very high. Percentage of hydro-carbons very low in all portions of block, except the outer. No solid hydro-carbons observed, even on surface (naphtalin, etc). Condition of wood shows injury from heat. Specimens are evidently suited for exposure *to dry air* only, under which circumstances the protection is sufficient."

To make a long story short, the process entirely failed to perform what was claimed for it; some portion of the works which were in New Jersey blew up, and the enterprise also exploded. Somewhat similar was the process of Constant and Smith (experiment No. 11), which provided an iron chamber in which the wood was placed and exposed to the smoky vapors of coal tar, generated in a separate retort. It did no good in preserving timber.

The same may be said of the Detwiler and Van Gilder process (experiment No. 12), of impregnating wood by resin dissolved in naphtha under pressure and at a high temperature.

In 1871, Mr. N. H. Thomas, of New Orleans, brought forward a proposal for preserving wood by immersing it in rosin oil. The process was thus described by the consulting chemist:

"The albuminous matters of the wood are coagulated, and the sap converted into steam by heat, and the wood thus treated is plunged into boiling rosin oil. The rosin oil permeates the pores of the wood, and not only prevents the introduction of moisture and oxygen, but it also, in virtue of it own indestructible and antiseptic properties (similar in most cases to those possessed by the materials used by the Egyptians in embalming dead bodies, and which has resisted decomposition for ages), preserves the wood from decay, and the destructive action of plants and animals."

After figuring up the enormous money savings which would result to various interests, *if* timber can be made to last by his process "25 or even 20 years," Mr. Thomas thus summed up the history and mystery of wood preservation: "Kyan invented a process of preserving wood in 1832; Burnett, in 1838; Bethell, in 1838; Margary, in 1837; Boucherie, in 1839; Payne, in 1841. Thomas patented his invention in 1871, after many years of experiments. Chloride of mercury, sulphate of copper, creosote, chloride of zinc, pyrolignite of iron, sulphate of iron, carbonate of soda are the materials used by the first-named inventors. Thomas uses rosin oil, which is cheap and healthy."

Works were erected in New Orleans, but after several years of experiments, it was found impracticable to impregnate wood with enough rosin oil to do any good, the difficulty being understood to be that it could not be rendered sufficiently fluid to fill the sap cells so as to prevent the intrusion of moisture. The enterprise was accordingly given up.

A somewhat singular proposal was that of the "American Wood Preserving Company," of the city of New York, which we have not included in our list of experiments, because we have not been able to learn that it ever tried any experiments.

In 1868 it issued a circular beginning as follows:

"By ancients, we have to say, that centuries ago, when the banks of the Nile became so densely populated, and the forests of Northern Africa disappeared and were converted to the uses of civilization, it be-

came necessary to adopt some means to preserve all articles that were composed of wood from mold or decay. Wood became valuable; the demand for it was imperative. How long it required to bring the processes of preservation to perfection, it is now impossible to find out; but that the Egyptians had a process, and that they did preserve wood and many other perishable things for thousands of years, there is no doubt."

"In the New York Historical Society rooms, corner Second avenue and Eleventh street, which contains the Egyptian Museum, can be seen *wood which is over four thousand years old;* also linen, towels, robes, ropes, canvas, paper, and numerous household articles and implements, all of which have been preserved and are now in good condition, so that, whatever may be said as to what can or cannot be done in this age, we have the incontrovertible fact before us that wood *has been* preserved *for over forty centuries.*" * * * * * "To rediscover the lost arts of the ancients has for years occupied the attention of the first minds of the old world; but it seems to have been reserved for *this inventor* to discover and apply practically one of the most important." * * * * "It will give us great pleasure to have you call at our office at your convenience, when we can undoubtedly satisfy you as to the merits of this great invention. We would very much like you to become interested in the enterprise, as we have no doubt it will prove a great success."

No explanation whatever was given in this circular as to the character of the process; but having indicated the exact museum where the Egyptian remains were to be found, and hinted that the inventor had rediscovered the method of their preservation, the public was invited to subscribe for shares in a company with a "capital stock of $1 000 000, divided into 10 000 shares of $100 each, of which 1 000 shares reserved for a working capital."

The process (which is believed by the committee to have been some method of applying rosin) does not yet seem to have come into general use.

Nothing is more curious than the way in which all the inventors of cheap processes for preserving wood quote the ancient Egyptians. That bodies, coffins and cloths should have been preserved for three or four thousand years appeals to their imagination; and, taking no account of the fact that the Egyptian mummies were kept in perfectly dry caverns, thoroughly protected from weather and moisture, they are sure to claim that their particular nostrum had something to do with it.

They claim this for the "Seely process" of employing creosote; for the "Robbins method" of using coal tar; for the "Thomas application" of resin; for the "Foreman process" of applying arsenic, etc., etc. And then they generally go to work figuring up the profits, much after the method of Col. Sellers of multiplying the profit on a bottle of eye water by the number of sore eyes in the world.

While on this subject we may allude to a New York inventor who did not "spoil the Egyptians," but tried instead an entirely original experiment. Having noticed that the scows which he used in his business were attacked by the *teredo*, he smeared their bottoms and sides with hot coal tar, and then sprinkled over it an even layer of *Scotch snuff*. Being a hater of tobacco, he believed this would be about the most disagreeable thing he could do to the *teredo*. Unfortunately, however, for the experiment, the coal tar rubbed off in spots, and the *teredo* got in.

Experiment No. 14 was tried in New Orleans in 1872. Cypress paving blocks were thoroughly boiled in creosote, or dead oil, in the still of Geo. H. Fletcher, and were laid in the yard of the New Orleans Gas Light Company. They are said to have been saturated with not less than 20 pounds, and probably with 25 to 30 pounds, of dead oil to the cubic foot, and are now (1885), after 13 years' exposure, as sound and perfect as when first laid.

Experiment No. 15 was only a temporary expedient to protect the sheathing of the East River Bridge caisson from the *teredo* while being sunk. Being now entirely buried beneath the mud, it is safe from attack. Only 2 pounds were injected per cubic foot.

Experiment No. 16 consisted of some planks, creosoted by the Hayford process, laid in 1872 in the basement floor of the factory of the Blake Manufacturing Company. These were yet in an unusually good state of preservation in 1882, although having been in contact with the flow of the tide since they were put down.

Experiment No. 18 was tried by the United States government upon the U. S. steamer "Vandalia." This vessel was built in 1873, of timber creosoted by the Hayford process, and when examined in 1882 was quite sound, while other ships built at the same time of untreated timber had received and still required extensive repairs. There seems to be no question that when creosoting is well done it is effective.

There must have been some careless work in experiment No. 19, in which some 12″ by 14″ timbers for gun platforms were treated at Boston, and laid in 1874 at Fort Jefferson, Dry Tortugas, Fla. They were so thoroughly rotted in 1878 that a cane was easily thrust through them.

One of your committee has heard it stated that the timber was simply swabbed over with an oil rag, and that the first works erected in Boston for creosoting would not stand 10 pounds pressure to the square inch, so that no effective work could be done.

Experiment No. 21 illustrates how necessary it is to know all the facts before forming a conclusion. Having been advised that favorable results had been accomplished at Rochester, N. Y., by the application of crude petroleum to farming machinery (experiment No. 21), the committee caused inquiries to be made in the oil regions as to the experience there.

Some general information was obtained as to the life of wooden oil tanks, duration of oil derricks, etc., etc., but it was rather indefinite.

At length a positive statement was received that on the Oil Creek Railroad, crude petroleum had been found to extend the life of hemlock ties to 14 years, and of oak ties to 18 years. That two gallons were required per tie, and that the ties, after being dried, should be put into boiling oil, the small end down. This seemed clear and definite, and the results promised to be so important that one of your committee went out to Titusville to investigate. He found that no ties had ever been actually treated by the process above indicated, but that it was thought that it would be the best way of applying petroleum should it be wished to preserve timber with it; that the experience consisted in observing the duration of ties in various side tracks on which crude oil was loaded, and where there was more or less dripping.

The side tracks were accordingly examined. Upon the principal one, still used as a track for loading oil, the ground was found to be completely saturated with petroleum; it oozed out and spurted up from beneath the ties upon the passage of each car, and here ties 12 or 13 years old were found to be as follows:

Hemlock, slightly dozy outside.
Black oak, " " "
White beech, dozy outside, sound inside.
White ash, sound and bright.
Black ash, " " "
White oak, perfectly sound.

Upon an adjoining side track, however, which had been used for loading oil for two or three years, and subsequently used for other purposes, the ties were found to have been once saturated with oil, but the ground was no longer in that condition. This side track was 9 years old, laid of hemlock ties, and these were badly rotted and in need of renewal.

The conclusion drawn was that crude petroleum, by excluding moisture, would prove a preservative so long as it continually saturated the wood, but that if merely injected once for all, its volatile nature would result in its evaporating out and leaving the timber unprotected.

Experiments Nos. 22, 23 and 24 illustrate the difference between good and bad work. Creosoting works at Galveston, Texas, creosoted in 1874 some 10 000 superficial feet of long leaf yellow pine paving blocks. The result was not satisfactory. The blocks upon being examined in 1881 showed that the creosote had penetrated the wood for about one-eighth of an inch only, and the center was dozy. Some other blocks, however, furnished for a stable yard (experiment No. 23), were of bastard or loblolly pine, which, in its ordinary condition, is a very perishable wood. These, when examined in 1885, proved to be perfectly sound, and upon being split open were found to be creosoted to the center.

The works above alluded to were principally established to creosote the

piles for the railroad bridge over Galveston Bay, which is some 2 miles long. This was in 1875 (experiment No. 24). In 1882, Mr. Temple, the Chief Engineer wrote:

"About one-half of the piles have been renewed, having been eaten by the *teredo*, caused evidently by dishonest creosoting, for last year, upon taking out the foundation of the draw bridge for the purpose of replacing it with brick, it was discovered that only two piles had been attacked out of a *selected lot* of 74."

"The piles were loblolly pine, known in most Southern States as 'fox tail,' or 'old field' pine, the life of which, not treated, is about two years here."

The next two experiments (No. 25 and No. 26) relate to the most thorough creosoting, and the most complete success which has been achieved in this country. They cover the preservation of timber both against the teredo and against decay, in the bridges of the New Orleans and Mobile Railroad, by Mr. J. W. Putnam, whose detailed account is given in Appendix No. 13. As this will be doubtless read in extenso, it seems sufficient to say here that it proves conclusively that when sufficient pains and expense are incurred creosoting is thoroughly efficient.

Experiment No. 27 relates to some 10 000 Virginia pine ties, which were creosoted in 1875–6, and laid upon the Central Railroad of New Jersey, beyond Bound Brook. These ties were allowed to season several months before being treated, and therefore absorbed the oil satisfactorily. They are now quite sound after seven or eight years' exposure, and are very little cut into by the rails.

Since then about 12 000 more have been treated at the Elizabethport works by Mr. Andrews, of this committee, whose views upon creosoting generally are herewith given in Appendix No. 14.

In this connection, we may allude to the "Webb" process (experiment No. 28), which dates back to 1871, and consisted in boring a hole lengthwise through the center of the tie or timber to be preserved, stopping up the hole with a plug, and then by a lateral hole, filling the cavity with creosote oil; the lateral hole being afterward plugged up with an iron screw, so that the operation could be repeated. A company with a capital of $2 000 000 was formed for the purpose of exploiting the portable boring machine with which the holes were to be bored, and of granting licenses to railroad companies upon a royalty of ten cents a tie. As the pores of the wood are mostly longitudinal with the grain, and are fewest and smallest about the heart, it was not found that the creosote thus barreled up in the ties disseminated itself much into the sap wood, especially during the winter, when creosote congeals at about 60° F. and becomes quite solid at lower temperatures.

Experiment No. 29 consisted of two yellow pine blocks, creosoted with 15 to 19 pounds to the cubic foot, which were furnished by Mr.

Andrews, and exposed with two untreated blocks from the same stick for 698 days in Delaware Bay. At the end of that time the untreated blocks were largely destroyed by the teredo, and the creosoted blocks were perfectly sound. It was also found that the latter had lost nothing in weight, thus indicating that the oil had resisted any chemical or mechanical tendency of the water to remove it.

The next five experiments (Nos. 30, 31, 32, 33 and 34) all pertain to the Hayford process as carried out by Mr. Andrews, and applied to ties, fence posts, piles and plank. The results are all favorable, so far as the limited time which has elapsed permits judgment to be formed.

Experiment No. 35 consists of some pine ties creosoted by Mr. Putnam, and laid in New Orleans. It may confidently be asserted that they will prove a success.

Experiment No. 36 represents the work done on the Houston and Texas Central, in creosoting ties at their own works at Houston, Texas. It has proved a success, and an interesting account of the process is given by Mr. M. G. Howe, in Appendix No. 15.

Experiment No. 37 consists in creosoting the piles in the long bridges across Lake Ponchartrain, New Orleans, for N. O. and N. Eastern R. R., the extension of the Cincinnati Southern Railroad. The company built its own works, and they have been under the superintendence of Mr. J. W. Putnam.

General Remarks on Creosoting.

It thus appears that there is no process of wood preserving the efficacy of which, when well done, is better established than creosoting, but there is also no process where more bad work has been done, either from design or ignorance. The reason of this will be apparent when the cost is considered.

Creosote now costs about one cent a pound, and the supply in this country is not equal to the demand, so that it has to be imported from England. For protection against decay alone, it seems necessary to inject by the present methods from 8 to 12 pounds per cubic foot, and this represents as many cents per cubic foot for the antiseptic alone. If we apply this to the smaller class of ties, averaging about 3 cubic feet each (and ties on many roads average 4 cubic feet), we have from 24 to 36 pounds (or cents) of creosote required for proper injection. To this is to be added the cost of handling the ties and working the plant, so that it may be said that properly to creosote ties will cost from 35 to 60 cents apiece, in accordance with their size and the amount of oil injected. This cost in most instances will be prohibitory, and it will generally be cheaper to let the ties rot and to replace them at present prices.

For timber in very wet situations or exposed to marine worms, creosoting is the only method which insures success. Whether it will

pay to use it will depend upon the exposure and the activity of the worms. Along the Gulf Coast, where the *teredo* cuts off a pile in eight months, there is no question about the matter, and creosoting *must* be resorted to. In our Northern harbors, where piles are destroyed in from five to twelve years, each case will have to be considered on its own merits. Where the sea water is fouled by sewage, or by the discharge of gas works, or the fermentation of vegetable refuse, such as the dust from an elevator, the *teredo* is inactive, or is driven away altogether, as he requires reasonably clean water to exist. For the same reason, he will not work much below the mud line. It is stated, however, that the *limnoria* is not injured by some varieties of sewage. How far these consideration may be relied upon will depend on the circumstances of each case, and it will not infrequently happen that it is cheaper, in view of cost and accruing interest, to let the *teredo* eat the piles, than to incur the expense of creosoting the timber to keep him out.

It seems to be established that it requires from ten to twenty pounds of creosote per cubic foot, depending upon the exposure, to protect timber against the *teredo*. The total cost, therefore, may be estimated at 14 to 24 cents a cubic foot, or $12 to $20 per 1 000 feet, b. m., for piles or square timber exposed to the attack of marine worms, and from 12 to 16 cents a cubic foot, or $10 to $14 per 1 000 feet, b. m., for timber exposed to decay alone.

There are creosoting works in this country as follows :

Somerset, Mass...........Old Colony Railroad.
Brooklyn, N. Y...........Eppinger and Russell.
Pascagoula, La...........New Orleans and Mobile Railroad.
Bonfouca, La............New Orleans and Northeastern Railroad.
Houston, Texas...........Houston and Texas Central Railroad.
Summerville, S. C........South Carolina Railroad.

Boucherie or Sulphate of Copper.

The name of Dr. Boucherie is generally applied to the *process* which he invented and extensively applied, of preparing wood by forcing a solution longitudinally through the pores of the wood by means of hydraulic pressure. As, however, he also patented the use of sulphate of copper, and his name became attached to the use of that antiseptic, it will be convenient here to classify experiments made with that substance under this head.

Dr. Boucherie was a distinguished French chemist, who between 1836 and 1846 made many elaborate researches and experiments upon the preservation of timber. He tried many substances, and at first recommended the use of pyrolignite of iron, but subsequently used sulphate of copper, which he considered more effective.

His first experiments were conducted by vital suction, that is, by tapping the living tree, and allowing the ascending sap to carry up a

preserving solution. This was not found to give uniform or satisfactory results, and Dr. Boucherie then invented the process which bears his name. This was practiced, either by applying a cap to the end of a freshly cut log, through which the solution was allowed to flow by pressure, or by sawing a log nearly through in the middle, raising it at the center slightly, so as to open the joint, placing a strip of tarred rope, or a rubber band, just inside the periphery of the cut log, and letting it spring back, so as to form a tight joint by pressing upon the rope or band. An auger hole bored diagonally into the cavity so formed then served to admit the solution under pressure.

This process, applied with a solution of about 1 pound of sulphate of copper to 100 pounds of water, has been extensively applied in France for many years, with satisfactory results. It was found, however, that to be successful it must be applied to freshly cut trees in the log only, and that this involved so much delay, moving about, waste and annoyance, that it has now been abandoned. These difficulties would be still greater in this country, and in the Northern States the process could not be applied at all during the winter (or season for cutting down trees), as the solution would freeze.

On page 279 is a list of the experiments which your committee have been able to learn about, as having been made with sulphate of copper in this country.

Comments on Sulphate of Copper Experiments.

The first experiment was carried out by Mr. W. W. Evans, on the Southern Railway of Chili, in 1857, and he informs your committee that in 1860, when he left that country, the ties were still good and in serviceable condition.

We give herewith, in Appendix No. 16, an interesting letter from Mr. E. Pontzen to Mr. Evans, on the subject of the Boucherie process.

Experiments Nos. 2 to 16, inclusive, were all tried with various modifications of the sulphate of copper process as introduced by Mr. W. Thilmany in this country. They date back to 1870 (experiment No. 2), when Mr. Thilmany was working and recommending the methods of vital suction and of the Boucherie hydraulic pressure system. After describing the foreign methods of injection with sulphate of copper, he states in his first pamphlet (1870): "This process resulted very satisfactorily, but it was found that the sulphate of copper became very much diluted by the sap, and when the same liquid was used several times, the decaying substance of the sap, viz., the albumen, was reintroduced into the wood, and left it nearly in its primitive condition."

He accordingly proposed a double injection, first by muriate of barytes, and secondly by sulphate of copper, forced through by the Boucherie process, and it is presumed that the ties of 1870, in experi-

RECORD OF AMERICAN EXPERIMENTS.

SULPHATE OF COPPER, OR BOUCHERIE.

No.	LOCALITY.	Year.	Process.	Material Treated.	Subsequent Exposure.	Results.	Authority.
1	Chili, S. A.	1857	Boucherie	Poplar ties	R. R. track	Favorable	W. W. Evans.
2	Cleveland, O.	1870	Thilmany	Ties	"	Favorable to 1875	J. R. Conrad.
3	Washington	1872	"	Paving blocks	Laboratory	Unfavorable	W. C. Tilden.
4	Pensacola	1874	"	Live oak	Teredo	Failure	W. H. Varney.
5	Charleston, S. C.	1875	"	Pine block	"	"	Q. A. Gilmore.
6	San Francisco	1876	"	"	"	"	C. S. Stewart.
7	Milwaukee	"	"	"	Pavement	Favorable, 1882	Schlitz Bg. Co.
8	Norfolk, Va.	"	"	Hackmetack	Teredo	Failure	P. C. Asserson.
9	Charlestown, Mass	1877	"	Various	Laboratory	Favorable	J. F. Babcock.
10	Wabash R. R.	"	"	Ties	R. R. track	Unfavorable	R. A. Houghton.
11	"	1878	"	"	"	"	W. S. Lincoln.
12	New York, Pennsylvania and Ohio R. R.	1879	"	"	"	"	C. Latimer.
13	Lake Shore and Michigan Southern R. R.	"	"	"	"	"	R. A. Houghton.
14	Cleveland and Pittsburgh R. R.	"	"	"	"	"	C. Latimer.
15	Charlestown, Mass.	1879	"	Spruce plank	Sidewalk	Success to 1882	S. G. White.
16	Baltimore and Ohio	"	"	Ties	R. R. track	Too recent	J. L. Randolph.
17	Hudson River R. R.	1869	Hamar	"	"	Success	E. W. Vanderbilt.
18	St. Louis	1882	Fladd	"	"	Too recent	H. Fladd.

ment No. 2, which showed favorable results when examined in 1875, were prepared by that process.

Subsequently Mr. Thilmany changed his mode of application to the Bethell process of injecting solutions under pressure in closed cylinders, and probably the paving blocks for experiment No. 3 were prepared in that way. The chemical examination of them by Mr. Tilden, however, showed the "saturation very uneven ; absortive power high ; block contains soluble salts of copper, removable by washing."

It was expected that the double solution, by forming an insoluble compound, would prove an effective protection against the *teredo.* Experiments Nos. 4, 5, 6 and 8, however, proved the contrary to be the fact.

The process, when well done, gave moderately satisfactory results against decay. A pavement laid in the yard of the Schlitz Brewing Company, in Milwaukee (experiment 7), was sound in 1882, after some six years' exposure. A report by Mr. J. F. Babcock, a chemist of Boston (experiment No. 9), indicated favorable results, and the planks in a rope-walk at Charlestown (experiment No. 15), laid in 1879, were yet sound in 1882

The experiments on railroad ties (Nos. 10, 11, 12, 13, 14 and 16), however, did not result satisfactorily. They seemed favorable at first, and great things were expected of them ; but late examinations made on the Wabash Railroad, on the New York, Pennsylvania and Ohio, and on the Cleveland and Pittburgh Railroad, have shown the ties to be decaying, and the results to be unfavorable.

This applies to the sulphate of copper and barium process. Mr. Thilmany has patented still another combination, in which he uses sulphate of zinc and chloride of barium, which has been noticed under the head of Burnettizing.

Experiment No. 17 was tried on the Hudson River Railroad. It consisted of 1 000 sap pine ties, which had been impregnated in the South, by the Boucherie process, with a mixture of sulphate of iron and sulphate of copper, under Hamar's patent. These ties were laid in the tunnel at New Hamburg, a trying exposure, and when examined, in 1882, several of them were still in the track. The process, however, was found to be so tedious that it was abandoned after a year's trial, and has not since been resumed.

In 1882 Mr. H. Fladd, of St. Louis, patented a method, which is the inverse of the Boucherie process (experiment No. 18). To the cap fastened to the end of a freshly cut log he applies a suction pump, and placing the other end into a vat, filled with the desired solution, he sucks up the preserving fluid through the pores or sap cells of the wood.

Quite a number of experimental ties have been prepared in this way, with various chemical solutions, chief of which was sulphate of copper,

and there is probably no question but that the life of the wood will be materially increased thereby.

Whether the process will prove more convenient and economical than the original Boucherie process can only be determined by practical application upon an extensive scale.

A considerable number of modifications and appliances for working the Boucherie process have been patented in this country ; but none of them seems to have come into practical use, probably because of the necessity for operating upon freshly cut logs, and the inconvenience of such applications.

The table on page 282 gives a record of various experiments with miscellaneous substances.

Comments on Miscellaneous Experiments.

Experiments Nos. 1, 2 and 3 relate to the Earle process, from which great results were expected from 1839 to 1844. It consisted in immersing timber, rope, canvas, etc., in a hot solution of 1 pound of sulphate of copper and 3 pounds of sulphate of iron mixed in 20 gallons of water. It was first tested on some hemlock paving blocks on Chestnut street, Philadelphia, and for a time seemed to promise good results. Experiments with prepared rope, exposed in a fungus pit, by Mr. James Archbald, Chief Engineer of the Delaware and Hudson Canal, seemed also favorable.

The process was, therefore, thoroughly tried at the Watervliet Arsenal, where it was applied to some 63 000 cubic feet of timber, at a cost of about 7 cents per cubic foot. The timber was used for various ordnance purposes, and while it was found to have its life extended, as would naturally be expected from the known character of the antiseptics used, its strength was so far impaired, and it checked and warped so badly, that the process was abandoned in 1844.

The committee is indebted to General S. V. Benet, Chief of Ordnance, for a full copy of the reports upon these experiments.

Experiments Nos. 4 and 7 represent the lime process, which has been applied to a considerable extent in France. The fact that platforms and boxes used for mixing lime mortar seem to resist decay has repeatedly suggested the use of lime for preserving timber. In 1840 Mr. W. R. Huffnagle, Engineer of the Philadelphia and Columbia Railroad, laid a portion of its track on white pine sills, which had been soaked for three months in a vat of lime-water as strong as could be maintained. Similar experiments were tried on the Baltimore and Ohio in 1850. The result was not satisfactory, as might be expected from the fact that lime is a comparatively weak antiseptic (52.5 by atomic weight, while creosote is 216), and from the extreme tediousness of three months' soaking.

Experiments Nos. 5 and 8 were tried with sulphate of iron, sometimes known as Payenizing, and the particulars of the former have been fur-

RECORD OF AMERICAN EXPERIMENTS—MISCELLANEOUS.

No.	LOCALITY.	Year.	Process.	Material Treated.	Subsequent Exposure.	Results.	Authority.
1	Chestnut street, Philadelphia	1839	Earle's	Hemlock blocks	Paving	Failure	S. V. Benet.
2	Watervliet Arsenal	1840	"	Oak timber	Gun carriage	"	"
3	Delaware & Hudson Canal	1840	"	Rope	Fungus pit	Favorable	"
4	Philadelphia & Columbia Railroad	1840	Lime bath	Pine stringers	Railroad track	Unfavorable	M. Coryell.
5	Boston & Providence Railroad	1844	Sulphate of iron	Ties	"	"	I. Hinckley.
6	Belvedere Railroad	1850	Salt	Hemlock	"	"	M. Coryell.
7	Baltimore & Ohio Railroad	1850	Lime	Ties	"	"	J. L. Randolph.
8	Rochester	1852	Payenizing	Ties	"	"	T. Hilliard.
9	Germantown, Ind	1855	Charring	Fence posts	Fence	Favorable, 1879	G. McGrew.
10	Pottsville, Pa	1857	Pyrolig'ite of iron	Timber	Railroad sills	Unfavorable	H. K. Nichols.
11	Erie Railway	1858	Boring	"	Bridges	Favorable	H. D. V. Pratt.
12	Galveston	1867	Casing	Piles	Bridge	Failure	W. H. Smith.
13	New York	1868	Beerizing	Lumber	Signs	Doubtful	S. Beer.
14	Wyoming Territory	1868	Natural soil	Ties	Railroad track	Preserved	J. Blinkinsderfer.
15	Chicago, Ill	1870	Foremanizing	Timber	Steamboat	Favorable, 1879	M. B. Brown.
16	Illinois Central Railroad	1871	"	Ties	Railroad track	Failure	L. P. Morehouse.
17	St. Louis	1871	"	Shingles	Roof	"	F. de Funiak.
18	Memphis & Charleston	1871	"	Ties	Railroad track	"	F. de Funiak.
19	Washington, D. C	1871	Tripler	Paving block	Laboratory	"	W. C. Tilden.
20	"	1872	Samuel	"	"	"	"
21	"	"	Taylor	"	"	"	"
22	Washington	"	Waterbury	"	"	"	"
23	"	"	Sulphate of iron	"	Pennsylvania ave	"	J. A. Partridge.
24	"	"	Sulphate of zinc	"	E street	"	"
25	"	"	Petroleum	"	16th street	"	"
26	Norfolk, Va		Red lead	Pine and oak	Teredo	"	P. C. Asserson.
27	"		White zinc	"	"	"	"
28	"		Tar and plaster	"	"	"	"
29	"		Kerosene	"	"	"	"
30	"		Rosin and tallow	"	"	"	"
31	"		Fish oil and tallow	"	"	"	"
32	"		Verdigris	"	"	"	"
33	"		Bark on pile	"	"	Good for 5 years	"
34	"		Carbolic acid	"	"	Failure	"
35	"		Tar and cement	"	"	"	"
36	"		Davis' compound	"	"	"	"
37	"		Carbolized paper	"	"	"	"
38	"		Paint	"	"	"	"
39	"		Thilmany	"	"	"	"
40	"		Vulcanized fiber	"	"	"	"
41	"		Charring	"	"	Good for 9 years	"
42	New Orleans & Mobile R. R	1872	"	Piles	"	Failure	J. W. Putnam.
43	" " "	"	" and oiling	"	"	Temporary prot'n	" "
44	Galveston & Houston R. R	{1870 / 1874}	Charring	"	"	" "	" "

nished by Mr. I. Hinckley, President of the Philadelphia, Wilmington and Baltimore Railroad, to whom your committee is much indebted for a large mass of information on the subject of timber preservation.

Mr. Hinckley has had longer and more varied experience on this subject than any other person in this country. Beginning with sulphate of copper in 1846, following with chloride of mercury in 1847, and chloride of zinc in 1852, going back to chloride of mercury, and again to chloride of zinc, using the latter until 1865, then using creosote to protect the piles against the *teredo* at Taunton Great River (experiment No. 2, creosoting), he has had millions of feet of timber and lumber prepared by the various processes, and has kindly placed at our disposal many original reports in manuscript and pamphlets which are now very rare.

Experiment No. 6 was made by Mr. Ashbel Welch, former President of this Society, and consisted in boring hemlock track sills 6 × 12 with a 1½-inch auger-hole 10 inches deep every 15 inches. These were filled with common salt and plugged up, as is not infrequently done in shipbuilding, but while the life of the timber was somewhat lengthened, it was concluded that the process did not pay.

Salt has been experimented with numberless times. It is cheap, but is a comparatively weak antiseptic, its atomic weight being 58.8 in the hydrogen scale, as against 135.5 for chloride of mercury.

Experiment No. 9 is included in order to notice the well-known and most ancient process of charring the outside of timber. In this particular case, the fence posts after charring were dipped for about 3 feet into a hot mixture of raw linseed oil and pulverized charcoal, which probably acted by closing the sap cells against the intrusion of moisture, which, as is well known, much hastens decay. The posts, which had been set butt-end upward, were mostly sound in 1879, after 24 years' exposure.

Experiments Nos. 41, 42, 43 and 44 did not, however, result as well, and numberless failures throughout the country attest that charring is uncertain and disappointing in its results.

Much ingenuity has been wasted in devising and patenting machinery for charring wood on a large scale to preserve it against decay. The process, however, is so tedious in comparison with the benefits which it confers, and the charred surface is so objectionable for many uses, that nothing is to be expected from the process upon a large commercial scale.

In 1857–8 Mr. H. K. Nichols tried sundry experiments (No. 10), at Pottsville, Pa., upon timber which he endeavored to impregnate with pyrolignite of iron by means of capillary action. Similar experiments had previously been thoroughly tried in France by Dr. Boucherie, but the result has not been found satisfactory.

In 1858 the Erie Railway purchased the right of using the Nichols

patent, and erected machinery at its Owego Bridge shop for boring a 2-inch hole longitudinally through the center of bridge timbers. This continued till 1870, when the works were burned, and in rebuilding them the boring machinery was not replaced. The longitudinal hole allowed a portion of the sap to evaporate without checking the outside of the timber and undoubtedly lengthened its life. It is believed there are yet (1885) some sticks of timber in the bridges of the road that were so prepared in 1868 or 1869.

In 1867 Mr. W. H. Smith patented a method of preserving timber, by encasing it in vitrified earthenware pipes, and filling the space between the timber and the pipe with a grouting of hydraulic cement. This was applied to the railroad bridge connecting the main land with Galveston Island (experiment No. 12), and so well did it seem to succeed at first that it was proposed to extend the process to railroad trestle work, to fencing, to supports for houses, and to telegraph poles. But after a while the earthenware pipes were displaced and broken, the process was given up, and Galveston bridge is now creosoted.

In 1868 Mr. S. Beer patented a process for preserving wood by simply washing out the sap from its cells. Having ascertained that borax is a solvent for sap, he prepared a number of specimens by boiling them in a solution of borax. For small specimens, this answered well, and a sign-board treated in that way (experiment No. 13) was preserved a long time, but when applied to large timber the process was found very tedious and slow, and no headway has been made in introducing it.

Experiment No. 14 was brought about by accident. Some years ago it was discovered that there was a strip of road in the track of the Union Pacific Railroad, in Wyoming Territory, about 10 miles in length, where the ties do not decay at all. The Chief Engineer, Mr. Blinkinsderfer, kindly took up a cottonwood tie in 1882, which had been laid in 1868, and sent a piece of it to the committee. It is as sound and a good deal harder than when first laid, 14 years before, while on some other parts of the road cottonwood ties perish in 2 or 5 years.

The character of the soil where these results have been observed is light and soapy, and Mr. E. Dickinson, Superintendent of the Laramie Division, furnishes the following analysis:

Sodium chloride	10.64	Calcium carbonate	22.33
Potassium	4.70	Magnesium	3.39
Magnesium sulphate	1.70	Organic matter	4.20
Silica	0.09	Insoluble matter	941.47
Alumina	1.94	Loss in analysis	4.
Ferric oxide	5.84	Traces of phosphorus acid and ammonia.	

The following remarks made by the chemists who made the analysis may be of interest:

"The decay of wood arises from the presence in the wood of sub-

stances which are foreign to the woody fiber, but are present in the juices of the wood while growing, and consist of albuminous matter, which, when beginning to decay, causes also the destruction of the other constituents of the wood.

"One of the means adopted to prevent the destruction of wood by decay is by the chemical alteration of the constituents of the sap.

"This is brought about by impregnating the wood with some substance which either enters into combination with the constituents of the sap or so alters their properties as to prevent the setting up of decomposition.

"The analysis of this soil shows that it contains large quantities of the substances (sodium, potassium chloride, calcium and iron) most used in the different processes of preserving or Kyanizing wood. It also contains much inorganic matter, which also acts as a preserving agent."

Some of the ties so preserved have been transferred to other portions of the track, and some of the soil has also been transported to other localities, so that it is hoped that in the discussion which may be expected to follow this report, some further light will be thrown on the subject, by an account of the results of these experiments.

Experiments Nos. 15, 16, 17 and 18 are most instructive, and convey a useful lesson.

In 1865 Mr. B. S. Foreman patented the application of a dry powder for preserving wood, which was composed of certain proportions of salt, arsenic and corrosive sublimate. This action was based upon an experience which he had had, when, as a working mechanic of Ellisburg, Jefferson County, N. Y., in 1838, he had preserved a water-wheel shaft by inserting such a compound in powder in the body of the wood, and ascertained that it was still sound some 14 years later.

His theory of the action of his compound upon timber was briefly this :

"That all wood before it can decay must ferment; that fermentation cannot exist without heat and moisture ; that the chemical property or nature of his compound, when inserted dry into wood, is to attract moisture, and this moisture, aided by fermentation, liquefies the compound ; that capillary attraction must inevitably convey it through the sap ducts and medullary rays to every fiber of the stick. * * * * * Were these crystallizations salt alone, they would soon dissolve, but the arsenic and corrosive sublimate have rendered them insoluble; hence they remain intact while any fiber of the wood is left.

"The antiseptic qualities of arsenic are also well known, and have been known for centuries. Chemical analysis of the *mummies of Egypt* to-day shows the presence of arsenic in large quantities in every portion of their substance. Whatever other ingredients may have entered into the compound that has been so potent in preserving from decay the bodies of the old kings of Egypt, and even the linen vestments of their tombs, arsenic was most certainly one."

The mode of application used by Mr. Foreman was to bore holes two inches in diameter three-fourths of the way through sticks of square timber, four feet apart, to fill them with the dry powder, and to plug them up with a bung. For railroad ties he bored two holes two inches in diameter, six inches inside of the rails, and filled and plugged them. Fresh cut lumber and shingles were prepared by piling layers upon each other, with the dry powder sprinkled between in the ratio of twenty pounds to the thousand feet of lumber. This was allowed to remain at a temperature of at least 458° F. until fermentation took place, when the lumber was considered fully "Foremanized."

The process was first applied to the timber and lumber for a steamboat, and in 1879 the result was reported to be favorable. It was then applied to some ties on the Illinois Central Railroad, where it did not succeed, and to some on the Chicago and Northwestern, where they seem to have been lost sight of, being few in number, so that your committee has not been able to learn the result.

Great expectations were, however, entertained, and a conditional sale was made to various parties of the right of using the process, notably, it is said, to the Memphis and Charleston Railroad for $50 000; and some ten miles of ties were prepared on that road, when the poisonous nature of the ingredients used brought about disaster.

Some shingles were prepared for a railroad freight house at East St. Louis, but all the carpenters who put them on were taken very ill, and one of them died.

The arsenic and corrosive sublimate effloresced from the ties along the Memphis and Charleston Railroad. Cattle came and licked them for the sake of the salt, and they died, so that the track for ten miles was strewed with dead cattle. The farmers rose up in arms, and made the railroad take up and burn the ties. The company promoting Foremanizing was sued and cast in heavy damages, and it went out of business.

In 1870 Mr. A. B. Tripler patented a mixture of arsenic and salt, and the succeeding year a specimen of wood prepared under that patent was submitted to the Board of Public Works of Washington, D. C., and examined by its chemist, Mr. W. C. Tilden (experiment 19). He found the impregnation uneven, and the absorptive power high, but he did not find any arsenic, though its use was claimed.

The Samuel process (experiment 20) consisted in the injection, first, of a solution of sulphate of iron, and afterward of common burnt lime. Mr. Tilden reported the wood to be brittle, and the water used to test the absorptive power to have been filled with threads of fungi in forty-eight hours.

The Taylor process (experiment No. 21) used a solution of sulphide of calcium in pyroligneous acid. It was condemned by Mr. Tilden.

The Waterbury process (experiment 22) consisted in forcing in a solution of common salt, followed by dead oil or creosote. It was also condemned by Mr. Tilden.

The examinations of Mr. Tilden extended to some fourteen different processes, most of which have already been noticed in this report, and their practical results given.

The Board of Public Works, however, laid down a considerable amount of prepared wood pavement in Washington, all of which is understood to have proved a dismal failure. After a good deal of inquiry your committee has been enabled to obtain information of the results of three of these experiments.

The pine paving blocks upon Pennsylvania avenue (experiment 23) were first kiln-dried, and then immersed in a hot solution of sulphate of iron.

The spruce blocks on E street (experiment 24) were treated with chloride of zinc, or, in other words, Burnettized; but the mode of application is not stated.

The pine blocks upon Sixteenth street (experiment 25) were treated with the residual products of petroleum distillation. It is stated that this was the only process in which pressure was used.

In from three and a half to four and a half years the blocks were badly decayed, and large portions of the streets were almost impassable, while other streets paved in the same year with untreated woods remained in fair condition.

It has been stated to your committee that this result, which did much toward bringing all wood preserving processes into contempt, was chiefly owing to the very dishonest way in which the preparation was done; that in fact there was a combination between the officials and the contractors by which the latter were chiefly interested "how not to do it," and that the above results, therefore, prove very little on the subject of wood preservation.

Through the kindness of the United States Navy Department your committee is enabled to give the results of a series of experiments (Nos. 26 to 41, inclusive) which have been carried on at the Norfolk, Va., Navy Yard, for a series of years, by Mr. P. C. Asserson, Civil Engineer, U. S. N., to test the effect of various substances as a protection against the *teredo navalis.* It will be noticed that the application of two coats of white zinc paint, of two coats of red lead, of coal tar and plaster of Paris mixed, of kerosene oil, of rosin and tallow mixed, of fish oil and tallow mixed and put on hot, of verdigris, of carbolic acid, of coal tar and hydraulic cement, of Davis' patent insulating compound, of compressed carbolized paper, of anti-fouling paint, of the Thilmany process, and of "vulcanized fiber," have proved failures.

The only favorable results have been that oak piles cut in the month January and driven with the bark on have resisted four or five years, or till the bark chafed or rubbed off, and that cypress piles, well charred, have resisted for nine years.

This merely confirms the general conclusion which has been stated

under the head of creosoting, that nothing but the impregnation with creosote, and plenty of it, is an effectual protection against the *teredo.* Numberless experiments have been tried abroad and in this country, and always with the same result.

There are quite a number of other experiments which your committee has learned about which are here passed in silence. The accounts of them are vague, or the promised results of such slight importance as not to warrant cumbering with them this already too voluminous report.

The committee also forbears from discussing the merits of the many patents which have been taken out for wood preservation. It had prepared a list of them, and investigated the probable success of many of them, but has concluded that it is better to confine itself to the results of actual tests, and to stick to ascertained facts.

Neither does the committee feel called upon to point out the great importance of the subject, and the economical advantages which will result from the artificial preparation of wood as its price advances. They hope, however, that the members of this Society, in discussing this report, will dwell upon this point.

We shall instead give as briefly as possible the general conclusions which we have reached as the result of our protracted investigation.

Decay of Timber.

Pure woody fiber is said by chemists to be composed of 52.4 parts of carbon, 41 9 parts of oxygen and 5.7 parts of hydrogen, and to be the same in all the different varieties. If it can be entirely deprived of the sap and of moisture, it undergoes change very slowly, if at all.

Decay originates with the sap. This varies from 35 to 55 per cent. of the whole, when the tree is felled, and contains a great many substances, such as albuminous matter, sugar, starch, resin, etc., etc., with a large portion of water.

Woody fiber alone will not decay, but when associated with the sap, fermentation takes place in the latter (with such energy as may depend upon its constituent elements), which acts upon the woody fiber and produces decay. In order that this may take place, it is believed that there must be a concurrence of four separate conditions:

1st. The wood must contain the elements or germs of fermentation when exposed to air and water.

2d. There must be water or moisture to promote the fermentation.

3d. There must be air present to oxidize the resulting products.

4th. The temperature must be approximately between 50° and 100° F. Below 32° F. and above 150° F., no decay occurs.

When, therefore, wood is exposed to the weather (air, moisture and ordinary temperatures) fermentation and decay will take place, unless the germs can be removed or rendered inoperative.

Experience has proved that the coagulation of the sap retards, but does not prevent, the decay of wood permanently.* It is therefore necessary to poison the germs of decay which may exist, or may subsequently enter the wood, or to prevent their intrusion, and this is the office performed by the various antiseptics.

We need not here discuss the mooted question between chemists, whether fermentation and decay result from slow combustion (Eremacausis) or from the presence of living organisms (Bacteria, etc.), but having in the preceding pages detailed the results of the application of various antiseptics, we may now indicate under what circumstances they can economically be applied.

Selection of Preserving Process.

In view of the differing cost of the various antiseptics used, and of the price of timber in this country, where it is still much cheaper than in Europe, we believe that the method to be selected for preserving wood (if any) depends almost wholly upon its proposed subsequent exposure, and that it has been a mistake hitherto to look to a single process for all purposes.

If the timber is to be exposed, in sea water, to the attacks of the *teredo navalis* and *limnoria terebrans*, there is but one antiseptic which can be used with our present knowledge. This is creosote or "dead oil," and the amount of it necessary depends upon the activity of the *teredo*, or rather upon the length of time during the year when the temperature of the water renders them active.

In our northern harbors, probably 10 to 12 pounds of creosote to the cubic foot of timber are sufficient, but in southern seas it is probably necessary to inject from 14 to 20 pounds per cubic foot.

Whether it will pay to do this depends upon so many local circumstances in each case that this cannot well be discussed here. If the timber is to be exposed in a very wet situation, creosoting is also the best process to use. It will cost from $10 to $20 per 1 000 feet, b. m., or 35 to 60 cents per tie.

The selection of the oil, as well as the quantity, is of importance. It was formerly believed that the antiseptic properties of dead oil arose from the presence of carbolic and cresylic acid, but a very able paper by Mr. S. B. Boulton, the leading authority on creosoting in England, read before the British Institution of Civil Engineers in 1884, seems to establish the fact that the preserving properties of dead oil, aside from the mechanical effect in keeping out moisture, are chiefly due to "Acridine," or one of the alkaloids or bases now known to exist in creosote oils.

* Angus Smith, 1869, "Disinfectants." S. B. Boulton, 1884, Institution of Civil Engineers, "On the Antiseptic Treatment of Timber."

If the exposure is to be that of a railroad tie, creosoting is doubtless the most perfect process to use; but in view of the expense, it may be preferable to use a cheaper process, dependent somewhat upon the location, as away from the seaboard creosote is not available, and transportation is expensive.

Sleepers of Baltic fir, unprepared, 9 feet long and 10 x 5 inches, generally cost, in England, about 90 cents each, unloaded, grooved and piled; and creosoting adds about 24 cents to this. So that the sleeper costs about $1.14 ready to go into the track, and is there laid with a chair under the double-headed rail, so that the latter does not cut into the wood. These sleepers, therefore, last 18 to 20 years, while in this country they would probably be cut into by our foot-rail in from 12 to 16 years; and, moreover, as the first cost of our ties, of corresponding timber, say hemlock or mountain pine, is only from 25 to 35 cents, we cannot afford to spend an equal sum in preserving them; and creosoting is notoriously more expensive here than in England.

With our present knowledge, and as a result of this investigation, we believe that Burnettizing is the advisable process to use for ties at present in this country. This, if well done (and it is nearly useless to do it otherwise), will cost 20 to 25 cents per tie, and a discussion of the economical results to be expected therefrom will be found in Appendix No. 17, this being a report made by Mr. Chanute to the New York, Lake Erie and Western Railroad in 1883, which that company kindly allows to be published.

Good results may be accomplished with sulphate of copper, but not only does this salt render wood brittle (more so, it is believed, than chloride of zinc), but as the copper attacks iron vessels, its use necessitates preserving cylinders of copper, and requires an expensive plant.

The great defect of all mineral salts is that they are easily soluble in water, and so wash out in time, and leave the timber unprotected. Hence the many attempts to patent some method of retaining them in the wood. What these may be worth must be determined by time, but the desirable combination for this country would seem to be the impregnation of the inside of the tie with some metallic salt to poison the germs of decay, and a thin coat of creosote outside to repel the intrusion of moisture.

If the timber is to be exposed in a comparatively dry situation, as in bridges, a trestle or a fence, the results of this investigation indicate that Kyanizing is a good process to use. It does not seem to impair the strength of the timber as much as Burnettizing, and the latter accordingly is not recommended for those parts of structures (chords, ties, etc.) which are to bear tensile strains.

Kyanizing costs about $6 per 1 000 feet, b. m., and success with it cannot be expected unless the work be well done. Caution will need to be observed in carrying it on, as corrosive sublimate is a violent poison.

Modes of Application.

The various modes of preserving wood which have been experimented with may be summarized as follows:

1st. Injecting in closed cylinders under pressure.
2d. Steeping or immersion.
3d. Boucherie process, hydraulic pressure to the log.
4th. Exposure to vapors.
5th. Absorption by capillary action.
6th. Inward insertion of powders or liquids.
7th. Charring. Application of heat.
8th. Painting.

The first three are the only ones which need concern us, and of these the first is on all accounts the best, most effective, and most expeditious. It is believed to be nearly impracticable to use on a commercial scale any of the other modes of application for the injection of antiseptics.

Conditions of Success.

It has already been stated that success in wood preservation has heretofore been the rule in Europe, and the exception in this country. This has chiefly resulted from the fact that, timber being cheap and interest high, it was generally more economical to let the wood rot than to go to the expense of doing the work well, and the business accordingly drifted mainly into the hands of designing men and quacks. The advancing price of timber, however, which has about doubled within the last twenty years, and the decline in the rate of interest, which has dropped about one-third within the same period of time, now make it practicable, and in many cases necessary, to preserve wood against decay in many parts of this country.

Your committee will therefore attempt to state the principal conditions to be observed to achieve success, so far as they have been disclosed by this investigation.

1. Select the appropriate process, in view of the subsequent intended exposure of the timber.

2. Select the more open-grained, porous and sappy varieties of wood to operate upon.

Antiseptics penetrate but little into the dense structure of white oak, burr oak and yellow or heart pine, and are of doubtful utility for white pine, chestnut or spruce, while they readily impregnate and preserve the following varieties of wood:

Hemlock,	Black oak,
Sweet gum,	Red oak,
Mountain pine,	Gray oak,
Loblolly pine,	Water oak,

Beech,	Sour oak,
Poplar,	Cottonwood,
Ash,	Maple.

Mr. J. B. Francis found in Burnettizing that white birch with the bark on was well preserved, while in hewed white birch the decay was complete, probably because of the difference in density and penetrability of the sap wood and the heart wood.

The experience of the English engineers is to the same effect, and they prefer to employ for creosoting the more open-grained kinds of wood, and sap wood rather than heart.

It will be found that there are great differences in the density of wood grown in various localities and sections of the country.

3. Operate upon the cheaper woods. Not only is the preserving effect less upon the more valuable kinds, but they are more durable naturally, and it is a question whether at present prices it will pay to prepare them against decay. The cheap woods, on the contrary, can be made to outlast the best woods in their natural state by a thorough artificial preparation.

For railroad ties it will be advisable to select the harder kinds of wood to guard them against cutting into by the rails, especially upon curves. Preservation, however, materially adds to the natural hardness of timber, and it is found to resist cutting by the rail, under ordinary traffic, from 12 to 16 years.

4. Extract the sap and water, as far as practicable, before injecting the preservative. It is obvious that a liquid solution cannot be forced in, unless there is a place for it, and yet most of the failures of valuable methods can be traced to neglect of this obvious requirement. Timber must be well seasoned either naturally or artificially before the antiseptic is injected, except in the case of the Boucherie process, which can only be applied to freshly cut logs.

The Europeans operate, as has been stated, upon timber which has been cut and seasoned six months or more, and hence they find little trouble in injecting the solutions. In this country we must operate chiefly upon green or freshly cut timber, and hence must resort to steaming, if we use the pressure method of injection. Very good results are accomplished by steaming, but the work must be well done, and at such heat and pressure as not to injure the fiber.

5. Put in enough of the antiseptic to accomplish the desired result, and make sure that its quality and strength are such as neither to injure the fiber of the wood nor to leave it unprotected.

6. After the wood is prepared allow it to dry as much as practicable before using. Its durability will be materially increased by getting rid of surplus moisture.

7. Let there be no undue haste in carrying on the work. This is sure to result in unsatisfactory preparation.

8. In laying prepared ties or timber in the track protect them from moisture or water, as far as practicable, by draining the road-bed.

9. Contract with none but reliable parties. As an inspection subsequent to the doing of the work, short of chemical analysis, does not establish the fact whether it has been well done, and the results cannot be detected for some years, there will always be a great temptation to do bad or careless work under contracts. The safe course, therefore, for those who decide to have timber preserved is either:

A. To do the work themselves, under the supervision of experts;

B. To contract it at a sufficient price to honest and skillful parties, keeping an inspector at the works to note the daily working when the magnitude of the order will warrant it; or,

C. Contract the work on such terms that the profits shall depend upon the results accomplished in preserving the wood against decay.

Will it Pay?

The question as to whether it will pay to preserve timber against decay seems to have been answered very positively in the affirmative in Europe. There seems to be, indeed, no longer any question there about it; preservation is looked upon as quite a matter of course, and public works which fail to avail of it are alluded to as neglecting an important economy.*

In this country, preservation of wood (except in an experimental way) has been the rare exception, but the time has probably arrived when, in many sections, an economy of twenty to fifty per cent. a year can be obtained in the maintenance of timber structures and cross-ties, by preparing them artificially to resist decay, while in other sections timber is still too cheap to warrant spending money to preserve it.

This depends upon the price. Thus where a white oak tie costs twenty-five cents and lasts eight years, if we spend twenty-five cents more in preparing it so that it will last sixteen years, we but double the life as well as the cost, and save only the expense of taking the old tie out, and placing the new tie in the track, at the end of the first eight years, if the price of ties in the meanwhile continues the same.

If, however, the oak tie costs seventy-five cents, and we can substitute a hemlock tie, which would unprepared last three and a half years, and cost thirty cents, and by preparing it extend its life to twelve years, at an additional cost of twenty-five cents, or even more, we then have a notable economy, both in first cost and in duration.

In the case of piles, which are cut off by the *teredo* in one or two years, as occurs in our Southern harbors, the case is plain. They must be creosoted, or great waste and increased expense will result. In cases

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* Funk's paper, Appendix No. 6. Discussion of Boulton, "The Antiseptic Treatment of Timber."

where they last eight to ten years, as in some Northern sections, it will depend partly upon the value of the structure which the piles sustain whether it will pay to creosote them or not.

In the case of bridges and trestles, much will depend upon the exposure, and the cost of maintenance, as well as upon the proximate exhaustion of suitable timber in the vicinity, and upon contemplated permanent renewals, while in the case of buildings, platforms, floors, etc., the ordinary wear from traffic will also have to be taken into account.

The most important factor will be the exposure (wet or dry), and consequent rate of decay. Thus all brewers find it very economical to preserve their floors; and mills, bleacheries, dye-houses, etc., largely resort to artificial preparation of timber because of their exposure to slopping of water, and consequent moisture in heated apartments.

The engineers and managers of the several works, therefore, will have to figure up for themselves, in view of the local circumstances of their case, and the present and prospective price of timber, whether the economy of artificial treatment is sufficiently attractive to induce them to resort to it.

The great consumers of timber are the railroads, and the managers of such enterprises have to be governed by a good many considerations, both of finance and of expediency, besides those of eventual economy.

Hitherto, aside from the past cheapness of timber, the principal objections to its preparation against decay have been the lack of information as to what results could be confidently expected, and the conflicting claims of the promoters of various modes of treatment, each of whom represented his process as absolutely the best under all circumstances.

The committee hopes that this report of the results of its investigations during the past five years will have done something toward removing the above mentioned obstacles to an important economy, but there still remains the objection that the results to be accomplished are somewhat remote, while the expenditure must be immediate.

Railroad managers naturally want to obtain immediate returns. They do not like to burden the revenues of the current year for the benefit of future administrations, and they are with reason jealous of every dollar that goes out now, even if it promises to save two or three dollars in the future; yet, now that close competition requires every possible economy to be availed of, that railroads must more largely depend upon saving money in their maintenance, in order to continue or to resume their dividends, and that companies in good standing can obtain new capital for expense-saving appliances at four and one-half or five per cent. a year, the time has probably arrived, in view of advancing prices and scarcity of timber, when some leading railroads will take steps to preserve it.

Computations of the money saving to be effected will be found in Appendix No. 6 and in Appendix No. 17.

In the former, Privy Councillor Funk estimates that in 1878, out of sixty millions of sleepers on the German railroads, twenty-five millions were impregnated, and that even with the extraordinary length of life stated for unprepared ties (13.6 years for oak and 6.1 for fir and pine), had the remaining thirty-five millions of ties been impregnated, there would have been a resulting economy of about one million of dollars a year, or some thirty-three per cent. on the cost of renewals.

This estimate is understood as having resulted in a material extension of tie-preserving in Germany, notwithstanding the fact that metallic ties have already been largely introduced in that country.

As regards the latter, a simple calculation shows that the time has not yet arrived when they can profitably be introduced in this country. They will cost, laid in the track, about $2.50 each, and were they to last forever (the estimated life in Germany is 20 to 40 years), the interest on the cost, at 5 per cent., would be 12½ cents a year a tie, or more than the annual charge of an unprepared white oak tie, costing 77 cents in the track, and lasting 7 years.

If, instead of 13.6 years for oak, and 6.1 years for fir and pine, unprepared, which life is said to obtain in Germany (probably in consequence of more thoroughly drained and ballasted road beds than our own), we assume a life of 8 years for oak, and 4 years for mountain pine and hemlock, as in better accord with experience in this country, we shall have the following computations of economy, upon the basis of Councillor Funk's paper, when oak sells at 50 cents, and hemlock at 25 cents a tie:

UNPREPARED TIES.

	Annual Charge.
15 000 000 oak, @ 50 c. = $7 500 000 ÷ 8	$937 500
20 000 000 hemlock, @ 25 c. = $5 000 000 ÷ 4	1 250 000
	$2 187 500

If it costs 25 cents each to impregnate them, we then have for lives of 16 and 12 years:

PRESERVED TIES.

	Annual Charge.
15 000 000 oak, @ 75 c. = $11 250 000 ÷ 16	$703 125
20 000 000 hemlock, @ 50 c. = $10 000 000 ÷ 12	833 333
	$1 536 458

Annual economy, $651 042.

When, however, the prices have advanced to 75 cents for the oak, and 30 cents for the hemlock, we have, with the same life and cost of preparation, the following comparison:

UNPREPARED TIES.

	Annual Charge.
15 000 000 oak, @ 75 c. = $11 250 000 ÷ 8	$1 406 250
20 000 000 hemlock, @ 30 c. = $6 000 000 ÷ 4	1 500 000
	$2 906 250

PRESERVED TIES.

15 000 000 oak, @ $1 = $15 000 000 ÷ 16	$937 500
20 000 000 hemlock, @ 55 c. = $11 000 000 ÷ 12	916 667
	$1 854 167

Annual economy, $1 052 083.

This illustrates how the economy of preservation increases as the price of ties advances.

The above mode of calculation is not strictly accurate. It omits the interest account, which would increase the cost as against the prepared ties, and it also omits the cost of periodical renewals, which would increase the cost of the unprepared ties.

Various methods have been employed for computing the economy of renewable structures. Local conditions and considerations vary so much, and there are so many circumstances which will force themselves into the account, that it is, perhaps, not wise to state any very definite rule in the premises. Your committee submit, however, three methods for such calculations in the appendix.

Appendix No. 18 is an estimate of the economy of creosoting ties, by Mr. E. R. Andrews, of this committee. Appendix No. 19 is an estimate of what increased life is necessary in order to justify a certain rate of expenditure in preserving timber, by Mr. B. M. Harrod, also of this committee, and Appendix No. 20 contains a formula for estimating the economy of various kinds of ties, furnished to your committee by an expert in such matters, the late Mr. Ashbel Welch, then President of this Society, and who thus renders a last service to the Society which regrets him still.

Respectfully submitted.

O. CHANUTE,
B. M. HARROD,
G. BOUSCAREN,
E. R. ANDREWS,
E. W. BOWDITCH,
C. S. SMITH,
J. W. PUTNAM,
G. H. MENDELL,
FREDERIC GRAFF, *ex officio*,
Committee on the Preservation of Timber.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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(Vol. XIV.—August, 1885.)

THE PRESERVATION OF TIMBER.

APPENDIX TO THE REPORT OF THE COMMITTEE.

APPENDIX No. 2.*

KYANIZING.

LETTER FROM J. B. FRANCIS, PAST PRESIDENT, AM. SOC. C. E.

O. CHANUTE, Esq.,

Chairman of Committee of the Am. Soc. of Civil Engrs. on the Preservation of Timber.

DEAR SIR,—In reply to your inquiry as to my experience in the preservation of timber, I have to say, that in the year 1848, as Chief Engineer of the Proprietors of the Locks and Canals on Merrimack River, who control and manage the water power furnished by that river at Lowell, Massachusetts, finding the need of some means of preventing the rapid decay of the numerous wooden bridges and other works maintained by them, I recommended the adoption of Kyanizing, and the

*Appendix No. 1 is a paper on The Preservation of Forests, by F. Collingwood, M. Am. Soc. C. E., and is published separately.

necessary works were erected. The process was patented in England by John Howard Kyan, March 31st, 1832, and soon after in the United States. It consists in impregnating the wood with a solution of bi-chloride of mercury, commonly called corrosive sublimate. Two wooden tanks were provided, each about fifty feet long, seven and a half feet wide, and four feet deep. In these the timber to be prepared is placed, the several layers being separated by laths, and the spaces filled with the solution, consisting of corrosive sublimate, one part, and water, ninety-nine parts. The timber is kept immersed a length of time depending on its least thickness, one day being allowed for each inch in thickness, and one day in addition, whatever the thickness; thus, for a six-inch timber seven days' immersion is allowed.

In 1850 we were induced to substitute Burnettizing for Kyanizing, it being said to be equally effective, much cheaper, and more expeditious. The two processes are alike, except that in Burnettizing chloride of zinc is the antiseptic. Corrosive sublimate, the antiseptic in Kyanizing, attacks iron, which interferes with the latter process being carried on in closed tanks from which the air is exhausted, and the solution injected under high pressure. Chloride of zinc is free from this objection. Burnettizing was carried on at Lowell for about twelve years by the expeditious process of exhaustion and pressure.

In 1862 we resumed Kyanizing, our experience of fourteen years having indicated that it was a much more effective preservative for our purposes than Burnettizing.

In 1849 the Pawtucket Street Bridge over the Northern Canal was built. It is a stringer bridge, about 120 feet long and 30 feet wide, supported by two piers and two abutments. The timber is northern white pine, and is all Kyanized. No repairs were made upon it, except the surface planking, until April, 1882, when three of the stringers were found to be so much decayed as to require renewal, and the lower ends of some of the braces, which came in contact with masonry or rock, were cut off and replaced. Some of the remainder of the timber had signs of decay, but is considered good for some years to come.

In 1850 the Proprietors of Locks and Canals built a picket fence, eight feet high and about six hundred and seventy feet long, of Kyanized spruce, around a small reservoir. It has been whitewashed from time to time, the last time about seven years ago, and it is now nearly bare. The posts are about six by eight inches, with three rails. I made an examination of the fence on the 11th inst., and found very little sign of decay above the surface of the ground, and this part of the fence is serviceable for many years longer. Below the surface of the ground, which is a dry gravel, all the posts are decayed more or less; about one-half of them are rotted off, or nearly so, at the surface of the ground, and the opportunity of this examination has been taken to batten them, with two and a half inch Kyanized spruce plank, six and a half feet long,

which it is expected will extend the duration of this part of the fence for many years. The remainder of the posts, although, as I have said, they are decayed, more or less, are considered serviceable for some time longer, without battening.

In 1862, when Kyanizing was resumed, for the purpose of obtaining some definite information as to its effects on different woods, specimens of twelve kinds growing in the valley of the Merrimack were obtained and prepared in the usual manner. The following is a schedule of the specimens, which were collected and prepared as above, in the summer and fall of 1862:

No. 1,	Old growth white pine,	18 feet	long,	9 x 9	inches.
" 2,	Sapling white pine,	"	"	"	"
" 3,	Northern hard pine,	"	"	"	"
" 4,	Spruce,	"	"	"	"
" 5,	Hemlock,	"	"	"	"
" 6,	Beech,	"	"	"	"
" 7,	Black birch,	"	"	"	"
" 8,	Yellow birch,	"	"	"	"
" 9,	Rock maple,	"	"	"	"
" 10,	White maple,	"	"	"	"
" 11,	Brown ash,	"	"	"	"
" 12,	Poplar, cottonwood,	"	"	7 x 7	inches.

The specimens, after being numbered as above, were cut in two, and one-half of each was Kyanized, and the other half retained in its natural state.

In the following spring, April 29th, 1863, they were set out in ground as posts, in two rows, about four feet of their length in the ground and about five feet out, where they still remain. The specimens have been fully exposed to the weather, the unprepared row being about two feet from the northwest side of a building, and the Kyanized row about six inches in front of them, all being about nine inches apart in the row. The soil is a coarse gravel, rather binding, but containing no clay, and is thoroughly drained by the cellar of the neighboring building, the walls of which are laid without mortar.

On the 13th inst. they were examined with reference to their state of preservation. The unprepared specimens, both above and below the surface of the ground, are very much decayed, and their forms are retained only by being boxed up on all sides with boards. The Kyanized specimens, although nearly all of them, in the parts below the surface of the ground, are somewhat decayed, retain their forms perfectly, and have the ring of sound timber when struck. There are differences in the amount of decay in different specimens. In all the specimens it appears to be confined to the parts below the surface of the ground and to within

an inch of the surface of the wood. The hemlock shows no signs of decay; the other specimens all show some signs of decay, and by inspection appear to have been preserved in the following order: Black birch, brown ash, beech, white maple, and rock maple.

The three specimens of pine, the spruce, and yellow birch follow; but are so nearly equally preserved that they could not be graded.

The Kyanized specimen of beech has some season cracks which contain fungus, from which similar cracks in the other specimens are free. The cottonwood is the most decayed, apparently extending to about an inch from the surface, but it is still firm and serviceable as a post, and the part above ground shows no signs of decay ; a sixteenth of an inch below the surface the wood is bright, and much harder than new wood. The unprepared specimen is decayed to an extent resembling black soil.*

Cottonwood does not grow naturally in the valley of the Merrimack ; our specimens were from a tree planted on the bank of a canal. As is well known, it grows very rapidly and is propagated with facility from cuttings. My experience with it is very limited, but as far as it goes, it indicates that, in localities suited to its growth, it might be cultivated with advantage as a timber tree and be made as durable as most other woods by the Kyanizing process.

The cost of Kyanizing depends mainly on the price of corrosive sublimate. This has been latterly much reduced. In 1848 it was $1.25 per pound ; the present price is from 50 to 55 cents per pound, depending on the cost of quicksilver. The average quantity used at Lowell is about five pounds per thousand feet, board measure, or 0.06 pounds per cubic foot, making the cost of the corrosive sublimate not exceeding $2.75 per thousand feet, board measure, or $3\frac{3}{10}$ cents per cubic foot. This is deduced from the amount used during several years, and is of course an average. There are considerable variations in the amount of corrosive sublimate taken up by the Lowell method, depending on quality, size and state of dryness of the timber. The other principal items that enter into the cost are labor and interest on cost of the plant. These will vary much in amount, depending on the extent and regularity of the operations.

The patent has expired long since, and there is of course no royalty to be paid.

If any further information on the subject, in my power, is desired, I shall be happy to communicate it.

Very truly yours,

James B. Francis.

Lowell, Mass., July 16th, 1885.

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* Characteristic specimens cut from the above were shown at the National Exposition of Railway Appliances, held at Chicago, in May and June, 1883, and are now in the Civil Engineers' Museum of the University of Illinois, at Champaign, Ill.

APPENDIX No. 3.

Kyanizing on the Eastern Railroad.

By H. Bissell, M. Am. Soc. C. E.

O. Chanute,

Chairman Com. Preservation of Timber, Am. Soc. C. Engrs.

Sir,—The following is a condensed statement of the Eastern Railroad Co.'s experiments for wood preserving:

About 1846 arrangements were made for Kyanizing track timber. The apparatus consisted of an iron cylinder 40 feet long, 4 feet in diameter; two tanks, each of same capacity as cylinder, one above and one below the cylinder; a steam boiler, with pumps, etc. The cylinder was filled with timber, closed and filled with steam, then allowed to stand for 20 minutes. This was supposed to take the sap out of the wood. The cylinder was then filled with the liquor from the upper tank, the liquor pumped in to a pressure of 150 lbs. per square inch. This was allowed to stand for 20 minutes, sometimes longer, the liquor then drawn off into the lower tank, and the timber removed. The solution used consisted of corrosive sublimate dissolved in hot water in the proportion of 1 pound to 30 gallons. There is no record of how much corrosive sublimate was absorbed per 1 000 ft. The boiler and tanks were protected from the action of the liquor by applying hot asphaltum varnish. The corrosive sublimate cost $1.50 per lb. The process was abandoned after a few years' trial, partly on account of cost, which averaged 7½ cents per cubic foot, and partly on account of changing from the method of laying rails on longitudinal timbers to using ties as at present. The timber treated was spruce and oak. Reports of results are vague and various. Nearly all admit that the process was beneficial, and it is claimed that some spruce timber lasted twenty years.

In 1879–80 works were erected at Portsmouth with the intention of using the Bethell process of creosoting. A building was erected containing two cylinders, each 6½ feet in diameter, one 66 and one 84 feet long, steam engine, air and liquor pumps and fixtures, the whole costing more than $12 000. The works were burned in April, 1880, when ready for starting. Owing to the scarcity and very high price of creosote oil, it was decided not to rebuild works for creosoting, but to try Kyanizing instead.

Four tanks, each 60 feet long, 9½ feet wide and 6 feet deep, were built of granite laid in cement, coated on the inside with coal tar applied hot. These tanks are covered by a frame building. A large tank of boiler iron, which was left from the wreck of the creosoting works, is used as a reservoir tank. For making steam, an old locomotive boiler is used. The tanks are filled with ties or timber, which is kept from floating by oak bars across the top of the tank. A solution of corrosive

sublimate is then pumped in from another tank, which is ready to be emptied, or from the reservoir tank, till the timber is covered. When the tank is filled, the liquor is warmed by blowing steam into it. The liquor used is corrosive sublimate, dissolved in water, in the proportion of 1 pound to 99 pounds. The corrosive sublimate is dissolved in a large cask of boiling water. The solution in this cask, which is very strong, is added to the liquor in the tanks as required to keep it of the requisite strength, which is determined with a hydrometer. The thickness of the timber determines the duration of the soaking; ties 6 inches thick require one week, twelve-inch timber, two weeks. When a tank is to be emptied, the liquor is pumped out before the timber is removed. The iron tank is given an occasional coat of hot coal tar, and the liquor has no effect on the iron. The pipes that come in contact with the liquor are of wood or rubber. The man who has the care of the work has in a few cases been nauseated for a short time by inhaling the steam while dissolving the corrosive sublimate, but by using proper care there was no necessity for this. The men handling the timber have never experienced any injury, and they are often needlessly careless.

Kyanizing was commenced in April, 1881. To March 1st, 1883, 388 000 cubic feet of ties, planks and timber have been treated, seven-eighths of the amount being ties. The average amount of corrosive sublimate absorbed has been $2\frac{6}{10}$ pounds per 100 cubic feet. The amount varies greatly, wood of rapid growth, with a large proportion of sap, taking much more than wood of slow growth. Seasoned timber not only absorbs more liquor, but leaves liquor in tank weaker than wet or green timber. No tests have been made to determine these differences. The average cost of the corrosive sublimate has been 51 cents per pound. The cost of labor varies greatly, as sometimes timber is taken directly from the cars to the tanks when first received; oftener it must be re-handled. The average cost for material, labor, fuel and interest on money invested in works and material is $3 per 100 cubic feet. The process was begun too recently to make any statement as to durability. The wood is contracted and made tougher, and is worked with more difficulty than before it is Kyanized.

Truly yours,

H. Bissell, M. M. W. *Eastern R. R.*

Salem, Mass., March 13th, 1883.

APPENDIX No. 4.

Burnettizing on Central Vermont Railroad.

St. Albans, Vt., April 28th, 1882.

O. Chanute, Esq.,

127 *East Twenty-third street, New York, N. Y.*

Dear Sir,—In reply to your favor of the 25th instant, I would say that in 1856 this road erected works for the purpose of extracting sap from wood and of infusing chemicals for the purpose of preservation. It was in use some four years, but it was so much work to get through with such large quantities of timber as are used upon a railroad that it was thought best to abandon the work; therefore, the boiler and fixtures were removed and sold, and nothing more was thought of the "Burnettizing" process until some three years since, when an old side track was removed, which had not been in use for several years, and which was nearly covered with earth and grass; still the hemlock ties were then found to be nearly sound, having laid there for nearly 25 years. I did not keep watch of other prepared timber put in at that early time, and as repairs are constantly going on upon a railroad, I am unable to say whether there are any other similar cases upon our line or not, but there is no doubt that the preservation of these ties was due to the process above named.

The reasons for abandoning the Burnettizing works upon this road would seem to be that the officers in charge at that time lost faith in the theory, and as it was an experiment, they did not learn of its value until recently discovered in the manner referred to. There is no question, in my opinion, regarding the value of the process.

Yours very truly,

J. W. Hobart, *Gen. Supt.*

APPENDIX No. 5.

Burnettizing on the Boston and Albany Railroad.

12 West Street, Boston, Mass.,
September 26th, 1882.

O. Chanute, Esq.,

Chairman of Committee on Preservation of Timber.

Dear Sir,—In reply to your circular and inquiries, I beg to give you the following statement:

In 1860 I constructed an iron girder deck bridge, to carry the tracks of the Boston and Worcester Railroad (now Boston and Albany) over the highway known as "North Beacon street," in the town of Brighton, now a part of Boston, and about 1 500 feet west of Brighton Station.

The bridge is nearly a hundred feet long, and was covered with Bur-

nettized green spruce ties, sawed 10 inches by 10 inches, and laid 10 inches apart.

I am informed by the man who had charge of the repairs that these ties had become badly checked, so as to be unable to hold spikes, after about nine years' use. They were renewed in 1869 or 1870 by white pine ties, in their natural state.

This second set of ties lasted only till 1875, *i. e.*, five or six years. They were then found somewhat decayed, and failed to hold the spikes, and were renewed by chestnut ties without any treatment. This third set lasted till the present season, when they were again renewed by untreated chestnut, that timber having served for a period of seven years.

I have no information as to the quantity of zinc chloride injected in the first set of ties. The work was done upon green timber, by first withdrawing the sap in an exhausted boiler, and afterward applying the solution of chloride, under a pressure of 300 pounds per square inch. The parties who did this have since discontinued the business for lack of patronage.

The traffic over this bridge has been large from the first, being now between fifty and seventy-five trains per day in each direction.

I am told that the burnettized spruce ties first used failed in a similar manner to untreated spruce, though only after a period of some nine years, while the latter will fail in such a place with four or five years' exposure. The failure is by cracking open and admitting air and water, after which the fiber depreciates rapidly.

My observation has led me to suppose that Burnettizing is of more avail where timber is covered with earth than when exposed to sun and air. Such exposure cracks and opens the timber just as soon as if it had not been Burnettized, and it then depreciates more rapidly than if not so checked.

If Burnettized spruce were used for ties in ordinary ballast, spaced as usual and subjected to a traffic as great as in the instance referred to, it would wear out long before it would suffer from decay. That is to say, the rails would crush into the wood and cut the tie half off, in much less than nine years.

This was prevented on the bridge referred to by the large bearing surface afforded by the unusual number of ties per rail, which were supplied for another reason, viz., to make a bridge floor strong enough to carry derailed wheels with impunity, a practice which I have followed on all railroad bridges for the past twenty-five years.

The process of Burnettizing, so far as my observation goes, does not affect the hardness of the timber; so that it is just about as well adapted to resist a crushing force, whether Burnettized or not. It does, however, undoubtedly put off decay; so that in all cases where timber is likely to fail through decay, and not by crushing or wearing out, the process will be of advantage, depending, of course, on local prices.

As far as I can learn, the present management on this railroad prefers to use chestnut without treatment, because under the existing circumstances this timber is cheaper than Burnettized spruce, and will resist decay till worn out or crushed, a period of some seven years in this case. But for roads of lighter traffic, or where the ability to resist decay would be of more consequence, the use of Burnettized or creosoted spruce would soon increase, if there were a larger supply of spruce in the market.

There is no kind of timber, suitable to hold spikes, in this part of the country, so cheap as spruce and hemlock, but it seems that this is not cheap enough, or rather that the chestnut is too cheap to make it worth while to Burnettize the spruce.

Many railroad companies in New England, especially on the slopes of the Connecticut Valley, grow their ties on their own lands.

Chestnut is found to produce a new crop once in fifteen to twenty years, by sprouting from the old stumps, a quality possessed by very few other trees.

The railroads along the seaboard of New England use swamp cedar ties. It is a soft, corky wood, quite unsuitable for a heavy traffic, but serves tolerably for passenger business, where no sharp curves are required. It generally fails by wearing out, *i. e.*, becomes unable to hold spikes, which loosen quickly, rather than failing by decay, except on roads with very light traffic.

I have used a limited quantity of Burnettized spruce for fencing rails and boards, and have found that it endures for eight or ten years, and is after that period apparently no further depreciated than untreated spruce becomes in about half that time. I have no means of learning what quantity of the zinc chloride was injected per foot.

As we are fast approaching a time when good timber will be a scarce article, my opinion is that there will be a growing demand for such preparations as are found best adapted to prolong its life, and that it will be an easier matter to so treat timber as to increase its power to resist decay than to strengthen its fiber against wear, while the latter item is in many cases quite as important as the former. The most efficient remedy for this trouble is undoubtedly to be found in providing more bearing surface for the loads. This may be done where timber is comparatively plenty by supplying a greater quantity of timber per mile, or in other words by applying the ties at more frequent intervals.

Where timber is more scarce the bearing surface may be increased by applying broad plates of iron at every tie, as is done in England with the reversible rails, or by more simple devices adapted to the flat-bottomed rail, by blocks of hard wood or iron plates. Such plates would probably last much longer than the timber, and serve for several sets of ties in succession. Moreover, they contribute much lateral support to the spikes, if spike holes are provided in them.

Yours very truly, EDWD. S. PHILBRICK.

APPENDIX No. 6.

German Experience with Preserved Railroad Ties.

[Translated for the *Railroad Gazette* from an article in the *Organ fur die Fortschritte des Eisenbahnwesens* by Privy Councillor Funk, of the Cologne and Minden Railroad.]

With the increase in the employment of iron as a material for the superstructure of the railroad in modern times, it might appear that any discussion as to the durability of wooden railroad ties and methods of increasing it had lost much of its interest. But when we come to consider that even where the results of experiments with the iron superstructure have been most successful, the roads will still be constrained to employ wooden ties for a long series of years; that more than half of the sixty millions wooden railroad ties that have been laid on the railroads of Germany and Austro-Hungary have been subjected to no treatment to prolong their life; and that millions of these rapidly deteriorating ties are annually replaced by others equally devoid of any means of preservation, while at the same time positive practical experience among the members of the German Railroad Union, extending over a period of thirty years, shows that several millions may be annually saved in the renewals of ties alone, we should have sufficient excuse for the occupation of valuable space in such a discussion. To these reasons must be added the urgent necessity existing in modern times for the utmost economy in railroad matters, and that those roads doing the least business will be most benefited by it, as in their cases the destruction of ties is caused by rotting more than mechanical wear. I am still further impressed with the utility of this subject by the results of my thirty-six years' experience in the construction and maintenance of the Royal Hanoverian and the Cologne and Minden Railroads. On both of those roads the importance of finding some method of prolonging the life of ties has been fully recognized, and since 1847 on one and 1849 on the other road, for periods of 32 and 30 years respectively, such methods of adding to the durability of the ties have been extensively employed. Then again, at the technical conventions of the Railroad Union, held in 1865 in Dresden, and in 1878 in Stuttgart, where this was one of the questions submitted for discussion, I was appointed reporter, and for the last few years I have had frequent inquiries from different parties respecting my experience in this matter on the Hanoverian and the Cologne and Minden Railroads, with a view to the introduction on other roads of the methods of impregnation practiced here.

We cannot be expected here to take into consideration, or even express an opinion on, the many different propositions and experiments

that have been made with a view to increasing the durability of wood; we shall confine ourselves rather to a discussion of such as have been most successful. But in order to comprehend and obtain a correct view of them, it is necessary to precede their description with a few general remarks.

I—General Remarks.

Wood, as is probably known to our readers, is made up of the woody fibers proper (cellulose) and the juices or sap that fill the interstices between them. The first are almost alike in composition in all woods, the chemical constituents being carbon 52.4 per cent., oxygen 41.9 per cent., hydrogen 5.7 per cent.; the sap differs in each kind of wood. The sap of oak is particularly rich in tannin, that of beech in vegetable albumen, and that of the different species of pine in resin. In all of them we find, in addition to the above, gum, vegetable glue, gallic acid, sugar, etc., in solution.

The pure wood-fiber is not particularly liable to decomposition; this is generally caused by the sap. This substance shows, like all organic bodies, a strong tendency to decompose, *i. e.*, to resolve itself into such combinations as are less liable to attack by putrefaction.

This latter stage is the result of putrefactive fermentation, induced by the oxygen of the atmosphere, and, when the sap is in this condition, the wood-fibers are affected by it.

The sap of felled wood goes over into putrefactive fermentation only under the following conditions:

1. When the access of air is permitted.
2. When the wood is in a damp state.
3. Under the influence of a moderate temperature, ranging, say, from 328° to 122° F.

If both air and oxygen are excluded from the wood, putrefactive fermentation cannot set in, and on this principle is founded the preservation of food in air-tight cans, and the almost endless durability of wood under water. The fact of moisture being requisite to a state of putrefaction is proved by the preservation of many substances by drying and kilning, and the great durability of the thoroughly dried wood in old buildings that are protected from any moisture. In the same manner we prove that warmth is necessary to putrefaction, by the discovery in the Siberian ice-fields of perfectly preserved mammoths, while, on the other hand, we know that at a temperature above 122° we commence the kiln-drying process.

We may, therefore, conclude that on the putrefactive fermentation of the sap, consequent on the presence of these three factors, depends the rotting of the wood, and the means of increasing its durability are consequently directed chiefly toward their frustration.

II—Methods of Increasing the Durability of Wood as now Practiced.

Firstly.—The sap must, as far as possible, be removed from the wood, and this expulsion, or rather diminution, of sap present, is effected either—

a. By felling in winter time, when there is least sap in the trees.

b. By girdling and barking the standing trees, as practiced in some districts.

c. By drying in the open air or in heated rooms.

d. By extraction by means of water.

e. By steaming in a closed vessel.

Secondly.—Such sap as may be left in the wood must be protected from putrefaction by preventing an occurrence of the conditions we have described above. This may be effected by—

a. Exclusion of air and moisture by painting with oil, tar, etc., or by nailing tin or felt paper over every part where the cross grain is exposed.

b. Removal of the moisture from wood by charring, which at the same time coagulates the albuminoids in the wood and forms a charred outer surface, through which substances favorable to putrefaction from the outside find great difficulty in penetrating.

c. Through the infiltration into the wood of, or its impregnation with, antiseptic fluids, by means of which putrefactive fermentation will be prevented, no matter how favorable to such a process the condition of the wood may be.

III—Modern Methods of Preserving Wood.

The latest methods of wood preserving are founded on infiltration or impregnation by antiseptics, and among those best known we reckon: (1) salts, green vitriol (sulphate of iron), blue vitriol (sulphate of copper), corrosive sublimate (bi-chloride of mercury), chloride of zinc, common salt (chloride of sodium), and potash (carbonate of potassa); in addition to these, we find used certain volatile oils, resins, aromatic substances, tannic acid, and, lastly, the product of the dry distillation of vegetable substances, containing principally pyroligneous acid and creosote.

The actual effects of these different substances are still comparatively unknown. Some are supposed by coagulating the albumen to secure it against putrefaction; others combine with the vegetable glue and form insoluble compounds incapable of fermentation; while others appear to prevent putrefactive fermentation by their simple presence.

Of the many different experiments that have been made with the substances just mentioned, either separate or combined, with a view to increasing the durability of wood, after long years of experience only

four have acquired any practical importance. These are the impregnation of wood with—

1. Sulphate of copper (blue vitriol).
2. Corrosive sublimate.
3. Chloride of zinc.
4. Creosote.

Experiments with the other methods have been quite abandoned, partly because the results were not satisfactory, and partly because the same effects were obtainable at less expense. The Boucherie process, so much used in France, which consisted of infiltration of the antiseptic fluid, generally sulphate of copper, into the wood of the tree while standing, thus forcing out the sap, has found few friends in Germany and Austria, and is now entirely abandoned there. The process was rendered still more difficult by the fact of its being only applicable at a certain time and in a particular place; it was expensive, and the results not so favorable as with impregnation.

The system of soaking the wood in a warm or cold antiseptic solution, or even boiling therein, has in like manner proved unsatisfactory, compared with impregnation, because the solution cannot permeate the wood thoroughly.

We may refer also to the process of steeping in corrosive sublimate solution, as practiced almost exclusively in England from 1838 until lately. It is now almost entirely given up. Nor has it been widely adopted on the Continent, although effective, for the reason that not only is it a very costly process, but it is likewise very injurious to the health of those who have to conduct it.

The impregnation of wood with the three above-mentioned and most used substances, sulphate of copper, chloride of zinc and creosote, is now accomplished universally in a closed tank, under a powerful pressure of from 7 to 10 atmospheres, which insures the greatest possible penetration of the antiseptic fluid into the pores of the wood. To aid and facilitate this penetration, and also to reduce the sap as much as possible, the wood is either previously highly dried, in creosoting, or thoroughly steamed in the impregnating tank, where chloride of zinc or sulphate of copper is employed. In the latter case the air is pumped out of the tank, as far as is possible, and the dissolved sap is thereby drawn out from the wood, to be drawn off by a proper discharge tap. If the impregnating fluid is then allowed to run into the tank it penetrates very readily, and under a powerful pressure, kept up for several hours, will permeate the wood from end to end.*

*Dr. Wöhler, of Göttingen, undertook the analysis of some oak ties that had been impregnated with chloride of zinc on the Hanoverian railroads under a pressure of eight atmospheres. In the innermost layer of the wood he found the chloride. This proves that if the solution had reached the innermost portion of the timber by simple impregnation the saturation would have been still more complete had the process been preceded by steaming.

Just as the process of infiltration with antiseptics was first invented and practiced by a Frenchman, Boucherie, so it was later with the process of impregnation, which was discovered by Breant in 1831 and patented by him in 1838, but he forced the solution into the wood by simple atmospheric pressure instead of putting on a direct mechanical pressure as now practiced.

The Englishmen, Bethell and Payen, secured a patent in 1840 on the process of impregnating wood with oil of tar and other bituminous substances containing creosote, by the application of a powerful pressure directly upon the impregnating fluid, after the wood has been, as far as possible, freed from air. The Bethell process of creosoting consists, consequently, of the following operations:

1. Thorough drying or steaming.
2. Removal of the air from the wood by the exhaustion of the impregnating tank.
3. Heating the liquid to a temperature 100° to 125° F. before admitting it to the tank, in order to render it sufficiently fluid.
4. Admitting the fluid and driving it into the wood by a pressure of from 7 to 10 atmospheres, maintained for 6 or 7 hours.

Impregnation with chloride of zinc was first proposed in 1838 by W. Burnett, in England, and there patented by him. At first, the process was confined to a simple steeping in the solution for 21 days, but this was ultimately abandoned for impregnation under pressure in a closed tank. The process met with little favor at first, better results being attributed to the use of sulphate of copper (blue vitriol). As soon, however, as it came to be considered that while the use of blue vitriol required costly copper tanks, iron would do for the chloride, and that in addition the latter was by far the cheaper of the two, it gradually grew into popularity. From England the process was carried to Bremen by the shipbuilder Wendt in 1846, and at first the telegraph posts of the line between Bremen and Bremerhaven were treated with the chloride. In 1847, as a further experiment, some 6 000 ties of the Hanover and Bremen Railroad, and soon afterward the timbers of the bridge over the Elbe, at Wittenberg, were subjected to the process.

Since 1851 chloride of zinc has been used exclusively on the Hanoverian railroads, and from a little later date on the Brunswick lines; and so it gradually spread over Germany, until at the present time in Austria and Germany it is employed by twenty different railroad managements.

The process consists in the following operations:

1. Steaming the ties from one to three hours, at a steam pressure of three to four atmospheres, for the extraction of the sap, assisted by running off the extracted sap and condensed steam at intervals of thirty minutes.
2. The air in the tank is gradually exhausted during one to three hours, until a vacuum of 20 to 24 inches mercurial column has been

obtained, this to insure a more complete extraction of the sap from the wood and a more thorough penetration of the impregnating fluid.

3. Admission of the impregnating fluid into the tank, and absorption by and forcing into the wood at a pressure of seven to ten atmospheres, maintained for three or four hours.

The impregnating fluid consists of chloride of zinc (metallic zinc dissolved in muriatic acid), containing from 28 to 30 per cent. of zinc (specific gravity 1.80 to 1.85), and diluted with thirty to sixty parts by volume of water to one of chloride of zinc. This dilution, sixty volumes of water, is recommended by Burnett, and experiments have proved that greater success attends the use of weak solutions than where the stronger are used. In Germany the chloride is generally dissolved in fifty times its volume of water.

Blue vitriol (sulphate of copper) is still used to a considerable extent in Germany for the impregnation of ties. In most cases this is not effected under pressure after a previous steaming and extraction of the sap from the wood, but only by steeping the ties or boiling them in the impregnating fluid. This may account for the very various, and in part very unfavorable, opinions expressed respecting impregnation with blue vitriol, which must be attributed more to the methods of impregnation than to the substance employed.

IV—Cost of Impregnation.

In considering the question, whether it is more advantageous to impregnate the ties before using them, or to use them in an unprepared condition, the cost of impregnation is of decisive importance, as the increase of durability attained by impregnation must bear proper proportion to the increased cost of the ties that have been subjected to this process. The expenses attached to impregnation must include, not only the cost of material and labor, but the interest payable and the addition to the sinking fund necessitated by the cost of erecting the impregnating works, and also the extra expense of transportation. There is no doubt that the outlay attached to the establishment of works for impregnating under pressure has frequently prevented railroad administrations from using this process.

Materials.—The materials employed vary considerably in price, and their cost depends also, to a great extent, on the amount of water that is used in making the solution of mineral salt. Chloride of zinc containing 28 per cent. of the metal costs from $1.55 to $2.21 per 100 lbs. The degree of dilution recommended by Burnett is 1 part by volume of the chloride to 60 parts of water. This, or a similar proportion, appears to be more commendable than the strong solution of 1 in 30 in use on some lines—the Brunswick Grand Ducal Railroad, for instance. When we impregnate under a pressure of 7 to 8 atmospheres, we find that oak ties containing 3.5 cubic feet of wood absorb an average of 0.35 cubic

feet; beech ties of like size, 0.68 cubic feet; and pine ties, 0.70 cubic feet of the impregnating fluid.

Blue vitriol costs $7.70 to $10 per 100 pounds, and, like the chloride, is used in solutions of varied strength, but in most cases with sixty parts by weight of water. The quantity absorbed would, with suitable wood and an equal pressure, be about the same as is given for chloride of zinc; but we must take into account that many roads using the blue vitriol only steep or boil their ties; the remainder employ almost exclusively a low pressure of one and a half atmospheres, equal to that naturally exercised by a column of water 39 to 40 feet in height.

Creosote obtained from Bethell, of London, costs $1.55 to $1.77; that manufactured in Germany by Bronner, of Frankfort-on-the-Main, $1.09 to $1.32 per 100 pounds. This creosote consists chiefly of coal-gas tar, which is distilled a second time, to render it more fluid under the influence of heat, by removing all the small coaly particles. Bethell's preparation is supposed to contain from 1 to 2 per cent. of creosote, but careful analysis showed that for the most part it contained no trace of that substance, and Bethell explained later that its presence was not essential to success.

The process still retains the name of creosoting, although of late the high-priced material imported from England has not been used.

With the cost of material must be reckoned the outlay for coal, oil, red lead, etc., used for the engines and boilers employed in impregnating, the prices of which are well known. The proportion per tie will depend on whether the engine serves one or more impregnating tanks.

The cost of labor is made up chiefly of the expense of handling the ties at the tanks and running the engine. The outlay for this purpose will depend on the perfection of the labor-saving contrivances. The most economical arrangement as yet devised is that in which the ties are loaded cylindrically on iron cars that can be run into the tank and out again on a track. This is effected by having one end of the tank removable and fastened by screw-bolts. The expense of interest and sinking funds for the capital invested depends on the amount of such capital required, and also on the number of ties that require impregnating. The more rapidly the process of impregnation is carried on, and the greater the number of ties to be impregnated, the less will be the proportion of expense to each tie.

The total cost of establishing an old-fashioned impregnating establishment for chloride of zinc on the Hanoverian railroads, with two impregnating tanks of 32 feet 8 inches in length and nearly 6 feet diameter, constructed to stand a pressure of eight atmospheres, with the building, steam engine, air and force pumps, reservoirs and cars to run into the tanks, but without the site or side tracks, was about $8 000. An earlier constructed apparatus, at the Minden station, built for creosoting, but now used for chloride of zinc, cost $19 600. It has been in

constant use since 1849 without requiring any considerable repairs, and in 1874 was removed to the neighboring depot of Porta, on the Weser. The impregnating apparatus at Brunswick, with two tanks, cost $13 500.

In the facts above presented we have an explanation of the wide difference in the cost of impregnating railroad ties according to the different systems. This cost averages, according to figures furnished by the German and Austrian railroad administrations, for each tie, as follows:

	Method of Impregnation.	Oak.		Beech.		Fir.	
		From	To	From	To	From	To
		Cts.	Cts.	Cts.	Cts.	Cts.	Cts.
1	Chloride of zinc	5.80	13.6	11.9	19.2	7.7	12.4
2	Blue vitriol.....	8.7	18.2	21.8	24.3	14.5	20.6
3	Corrosive sublimate (not under pressure)	20.1	24.3	....	....	24.3	38.8
4	Creosote (under pressure)............	21.4	32 8	....	43.2	35.5	55.9

Impregnation with chloride of zinc is therefore by far the cheapest process, costing only one-half to one-fourth as much as creosoting, its most successful competitor.

V—Results of Impregnation.

The most interesting and important question with regard to the impregnation of ties concerns the results.

In consequence of the utter want of experience, definite information on the subject could only be obtained by careful observation and record. This was rendered extremely difficult by the many different factors derived from the nature of the wood, and the circumstances in which it was used, that had to be taken into consideration. Whether the timber was grown on light or heavy soil, whether the ties were laid in clean and porous, or in clayey and impermeable ballast; whether the upper surface is exposed to sun and air, or whether it is covered with ballast; whether the ties were first dried, or whether they were impregnated in a green condition, etc., all must exercise great influence on our question. All these circumstances received, when the observations were first undertaken, very little notice, as experience in the results of impregnation was entirely wanting, and it was therefore necessary to direct particular attention to them.

The statistics contained in the reports of the transactions of the technical conventions of the German Railroad Union, held in Dresden in 1865, in Munich in 1868, in Dusseldorf in 1874, and in Stuttgart in 1878, are unfortunately not so complete as might be wished, although the Dusseldorf meeting considered them sufficient to justify the following deductions :

"By means of impregnation a longer life is secured to the ties. The substances best adapted for this purpose are chloride of zinc and such as contain creosote. Blue vitriol and corrosive sublimate, in consequence of their higher cost and the difficulty of employing them, can only be considered as of secondary value."

At the Stuttgart technical convention it was ascertained that in 1877 the ties on 40 railroads in the German Railroad Union were impregnated, while in 1868 the process was only in vogue on 28; of these 40 roads, 5 used blue vitriol, 8 corrosive sublimate, 13 creosote, 20 chloride of zinc, and 5 a mixture of chloride of zinc and creosote. To understand these figures it is necessary to state that on several roads more than one system of impregnation is employed.

According to the unanimous opinion expressed by the roads taking part in the Stuttgart convention that have used any one of these systems of impregnation, the success of the process is indisputable, and none of these administrations have any idea of abandoning it.

All that is left for us to do is to choose the method that is most advantageous from a financial point of view, and in this respect the abovementioned convention expressed itself as follows:

"As the experience of those railroads that have for from 25 to 26 years impregnated their ties with chloride of zinc under pressure after steaming and abstracting the sap (Hanover railroads, Brunswick railroads and others) has been very satisfactory, and as this system costs only one-half to one-third as much as impregnation with creosote, or corrosive sublimate, the majority of railroads have adopted the chloride of zinc process."

In spite of these favorable expressions of the latest technical convention, there still remain in Germany and Austria some 57 roads which do not impregnate their ties. We will, therefore, in the accompanying tables compare, according to the latest and most trustworthy results of the experience of the German Railroad Union, the durability of unimpregnated with that of impregnated ties, which will be found to support the theory that the impregnation of railroad ties is of financial importance.

TABLE A.

Comparative Durability of Unimpregnated and Impregnated Oak Ties.

The number of ties changed, expressed in percentage of the original laid, was:

From the First Year to the	Unimpregnated Ties.					Impregnated Under Pressure With		
	Emperor Ferdinand Northern R. R., 615 968 ties.	Hanover R. R., 565 261 ties, laid in 1845–47.	Cologne-Minden R. R., 140 108 ties, laid in 1846–48.	Berlin-Potsdam, 180 204 ties, laid in 1846.	Altona-Kiel R. R., 167 000 ties, laid 1843–44.	Chloride of Zinc—Hanover R. R., 168 690 ties, laid in 1854.	Creosote—Cologne-Minden R. R., 67 678 ties, laid in 1854.	Chloride of Zinc—Rheine-Emden R. R., 18 600 ties,* laid in 1854–55.
5th, inclusive....	0.54	0.61	0.29	.....	0.06	0.15	0.05	......
6th, "	1.25	1.14	1.88	0.34	0.19	0.20	0.30	......
7th, "	3.95	3.88	6.11	1.81	0.33	0.37	0.32	......
8th, "	8.93	6.04	11.27	3.46	1.13	0.52	0.53	......
9th, "	18.74	10.48	16.36	5.35	3.84	1.18	0.53	......
10th, "	25.70	14.92	20.29	8.12	6.71	2.20	0.78	1.0
11th, " ...	41.46	19.92	26.34	11.49	10.38	4.38	0.81	......
12th, "	74.73	26.09	38.97	15.63	16.64	8.02	1.02	......
13th, "	......	31.61	46.06	24.28	23.32	11.50	8.60	......
14th, "	......	34.33	52.73	30.89	38.27	....	12.79	5.2
15th, "	......	35.91	63.13	41.69	46 83	....	19.94	6.5
16th, "	......	43.51	71.39	50.01	55.29	....	21.82	7.8
17th, "	......	49.93	80.64	60.43	64.87	(20.73) †	26.03	9.5
18th, "	......	60.77	99.09	66.60	74.16	(27.97) †	30.09	12.2
19th, "	......	72.42	......	73.40	83.13	(31.38) †	36.72	21.4
20th, "	......	77.32	......	75.40	91.57	....	......	24.0
21st, "	......	79.33	......	......	93.35	....	......	27.88
22d, "	......	81.35	......	......	94.52	....	......	31 30
23d, "	......	......	......	......	95.31	....	......	35.33
24th, "	......	......	......	......	96.19	....	......	36.35
Average life......	10 years.	16 years.	13.5 years.	16 years.	15.1 years.	19.6 years.	19.5 years.	25 years.

Average life of 1 334 215 unimpregnated ties on 12 German railroads, 13.6 years.

*These 18 600 oak ties used on the Rheine-Emden Railroad were joint ties; the 161 615 pine ties in the following table were intermediate ties.

† The figures in brackets refer to 6 246 ties between Bremen and Sebaldsbrück.

TABLE B.

Comparative Durability of Unimpregnated and Impregnated Fir Ties.

The number of ties changed, expressed in percentage of the original number laid, was :

From the First Year to the	Unimpregnated Ties.				Impregnated Ties.			
	Tilsit-Intersburg R. R., 68 291 ties laid in 1864.	Leipzig-Dresden R. R., 93 543 ties laid in 1856.	Schleswig R. R., 146 800 ties laid in 1854.	Oppeln-Tarnas R. R., 79 200 ties laid in 1856–57.	Boiled in blue vitriol—Berlin-Potsdam, Magdeburg R. R., 36 640 ties laid in 1850.	Steeped in blue vitriol—Lübeck-Bückden R. R., 60 000 ties laid in 1851.	Blue vitriol under pressure—Magdeburg-Wittenberg R. R., 111 044 ties laid in 1849-50.	Chloride of zinc under pressure—Rheine-Emden R. R., 161 515 ties laid in 1854–55.
5th, inclusive......	1.16	11.72	2.0	16.6	0.93	0.0	0.2	0.06
6th, "	4.02	23.11	8.2	37.5	1.97	0.0	0.8	0.16
7th, "	14.20	35.86	22.0	58.0	2.94	0.0	1.5	0.31
8th, "	32.02	47.10	51.5	77.0	4.73	1.0	3.0	0.60
9th, "	44.70	61.50	62.5	84.9	7.98	2.5	4.1	0.69
10th, "	55.82	73.70	75.5	91.9	12.11	5.8	5.8	1.10
11th, "	68.08	86.40	80.0	98.9	17.47	19.0	8.5	1.30
12th, "	78.52	100.00	86.5	......	23.99	30.6	12.6	1.40
13th, "	82.77	......	90.7	......	31.14	40.6	14.9	1.60
14th, "	......	......	......	......	38.50	49.0	17.3	2.7
15th, "	......	......	......	......	50.20	57.0	19.4	3.5
16th, "	......	......	......	......	66.20	66.0	20.9	5.7
17th, "	......	......	......	......	......	69.0	......	8.4
18th, "	......	......	......	......	......	......	......	13.3
19th, "	......	......	......	......	......	......	......	20.8
20th, "	......	......	......	......	......	......	......	26.9
21st, "	......	......	......	......	......	......	......	31.6
22d, "	......	......	......	......	......	......	......	37.3
23d, "	......	......	......	......	......	......	......	42.3
24th, "	......	......	......	......	......	......	......	46.3
Average life........	9.4 years.	7.9 years.	8.6 years.	7.0 years.	14.0 years.	13.9 years.	16.0 years.	22.8 years.

Average durability of 882 407 unimpregnated ties on 6 German railroads = 7.2 years.

Average durability of 831 341 ties impregnated, according to different systems, on 13 German railroads = 14.0 years.

TABLE C.

Durability of Pine and Beech Ties.

The number of ties changed, expressed in percentages of the original number laid, was:

From the First Year to the	Pine Ties.				Beech Ties.		
	Unimpregnated.		Impregnated with		Impregnated under Pressure with		
	North and South Union R. R., 233 640 ties laid in 1858.	Western R.R. of Saxony, 26 720 ties laid in 1858.	Chloride of Zinc by Steeping—Altona-Kiel R. R., 3 899 ties laid in 1852.	Blue Vitriol by Steeping—Aachen-Dusseldorf R. R., 32 348 ties laid in 1852–53.	Chloride of Zinc—Hanover R. R., 81 002 ties laid in 1852.	Creosote—Cologne-Minden R. R., 21 440 ties laid in 1855.	Chloride of Zinc—Brunswick R. R., 600 ties laid in 1852.
5th, inclusive...........	40.6	24.9	24.0	14.0	0.86	0.04	......
6th, "	62.4	66.5	33.0	21.0	1.56	0.04	......
7th, "	81.3	100.0	50.0	31.0	2.19	0.15	......
8th, "	94.6	......	73.0	41.0	2.72	0.76	......
9th, "	100.0	......	84.0	41.0	3.70	1.64	2.2
10th, "	......	......	91.0	49.0	4.90	3.91	7.2
11th, "	......	......	95.0	52.0	7.68	7.62	11.7
12th, "	......	......	98.0	......	13.06	13.66	39.3
13th, "	......	......	98.0	......	19.68	17.57	40.0
14th, "	......	......	98.0	......	25.40	20.05	40.0
15th, "	......	......	100.0	......	34.50	22.49	42.0
16th, "	......	......	......	......	......	24.48	......
17th, "	......	......	......	......	......	28.09	......
18th, "	......	......	......	......	......	31.89	......
19th, "	......	......	......	......	......	44.97	......
20th, "	......	......	......	......	......	46.91	......
The average durability is...	5.2 years.	5.1 years.	6.6 years.	9.6 years.	14.8 years.	17.8 years.	13.0 years.

SUMMARY.

From the statements furnished above, as well as from other sources of information respecting the durability of ties, we will gather in concise form the most important conclusions.

1. The average life of unimpregnated ties on the German and Austrian railroads has been as follows, up to the present time:

For oak ties	13.6	years.
" fir "	7.2	"
" pine "	5.1	"
" beech "	3.0	"

2. The average life of ties impregnated in a rational manner with creosote or chloride of zinc, under a powerful pressure, reaches:

For oak ties	19.5	years.
" fir "	14 to 16	"
" pine "	8 to 10	"
" beech "	15 to 18	"

3. The average life of 831 341 pine ties on 13 German railroads, impregnated on various systems, is calculated at 14.0 years.

4. The plan of simply steeping the ties cold in the impregnating fluid, or warming them or boiling them therein, has been abandoned by most of the roads formerly practicing it, owing to its unsatisfactory results, and the system of impregnating under a strong pressure is being universally adopted.

5. A few roads steep their ties in corrosive sublimate without pressure, and are satisfied with the result.

6. The employment of blue vitriol for impregnation is being more and more abandoned in favor of chloride of zinc, because:

a. The result is not so satisfactory, which may be owing to the fact that only steeping, or at most a weak hydrostatic pressure, is employed for impregnation.

b. Because an expensive copper tank is required for the purpose.

c. Because the material itself is almost four times as expensive as chloride of zinc.

7. The results of impregnation of chloride of zinc and creosote are about equal. But as the impregnation with creosote costs about three times as much as with chloride of zinc, a majority of the German railroads have gone over to the latter.

8. An idea of the systems of impregnation now in use, compared with those employed in the years 1865 and 1868, may be gathered from the following table compiled from the report of the technical convention held in Stuttgart in 1878. (See Note at end of Appendix.)

9. In addition to the methods of impregnation, we have other circumstances that exercise considerable influence on the durability of the ties. Among them we may reckon especially the amount of traffic over

the road, the permeability of the ballast, the protection of the ties against rapid changes of temperature or degree of moisture by covering them with a layer of gravel, and the extent to which the ties had been dried before and after impregnation, and also before being laid.

Although we possess few figures respecting the influence of the above-mentioned conditions on the durability of ties, we find that the German Railroad Union collected a quantity of general experience, the result of which was the adoption of the following conclusions, unanimously or by a great majority, at the technical convention at Stuttgart in 1878 :

a. The ballast most favorable to the durability of the ties is that which is cleanest and most free from earthy particles, that allows the water to run through it easily, and is least affected by the vicissitudes of the weather.

b. That a covering of clean gravel, which protects the ties from the influence of the sun's rays, or, in other words, from light, and also from the rapid changes from heat to cold, and from wet to dry, is most advantageous for the preservation of the ties.

c. That a thorough air-drying of the ties before laying them on the road has a favorable effect on the durability, both of impregnated and unimpregnated ties.

d. That ties made from timber felled in winter, especially when they are not impregnated, have been found, after many years' experience, to possess much greater durability than those made from trees felled in the summer.

e. That, to insure successful results, all ties that are to be impregnated with creosote under pressure, or by steeping in corrosive sublimate, must be thoroughly air-dried or artificially dried before impregnation, whereas such ties as have been steamed and deprived of their sap previous to being impregnated in partial vacuo with chloride of zinc or blue vitriol do not require to be dried.

While from the foregoing we may recognize the advantages of impregnating ties, even in the case of a road which can obtain wood at comparatively low prices, I will add a few calculations, which, although to a certain extent based on estimates, will show the great economical importance of impregnating railroad ties.

Of the 60 000 000 ties—speaking in round numbers—that are laid on the German and Austro-Hungarian railroads, about 25 000 000 are impregnated; the remainder being unimpregnated. Of the latter, some 15 000 000 are of oak; the remainder of pine, fir and other soft woods. According to the foregoing tables, the average life of an oak railroad tie, when unimpregnated, is about 13.6 years; when impregnated, 19.5 years. And the average life of fir and pine ties, unimpregnated, is 6.1 years; impregnated, 12.0 years.

Taking the average price of unprepared oak ties at $1, and pine and

spruce ties at 62½ cents, and supposing the cost of impregnation, including interest and sinking funds for the capital invested in the construction of the impregnating works and transportation (taking into consideration the constant spread of the system of impregnating with the cheap chloride of zinc), to be about 12.5 cents for oak ties, and for pine or spruce ties about 15.0 cents, we obtain the following results in round numbers: The 15 000 000 unimpregnated oak ties have cost $15 000 000, and represent, with their average life of 13.6 years, a yearly expenditure of $1 102 500. The 20 000 000 unimpregnated fir and pine ties, at 62.5 cents, have cost $12 500 000, and the necessity of replacing them every 6.1 years represents an annual outlay of $2 047 000. The cost of maintaining the unimpregnated ties amounts therefore to $3 150 000.

Had they been properly impregnated the 15 000 000 oak ties at $1.12½, including impregnation, would have cost $16 875 000, and, with an average life of 19.5 years, would have entailed a yearly expense of $865 000 for replacement; while the 20 000 000 pine and spruce ties, at the rate of 77 cents, would have cost $15 500 000, and, lasting an average 12 years, they would have cost annually $1 350 000 for replacement.

The cost of replacing the 35 000 000 unimpregnated ties we have shown to be $3 150 000; while, had they been impregnated, they would only have cost annually $2 215 000. *By impregnating those ties we should, therefore, have saved each year* $935 000.

Such figures call loudly enough for the universal introduction of the impregnation of ties, and require no further explanation.

There is but one thing more we should like to say.

Those who do not find the foregoing, which is the experience hitherto obtained of the success and financial importance of impregnation, sufficiently convincing, will have little chance of being speedily convinced, as the continuance of statistical observations respecting the life of impregnated and unimpregnated ties has greatly increased in difficulty, and indeed has almost ceased.

Toward the end of the period of renewal the ties that were originally laid are very difficult to distinguish from those that were replaced later. A second period, when further experience will be possible, will only occur when the proceeding recommended at the technical convention of 1868 in Munich, and confirmed and again recommended at the Stuttgart convention in 1878, has been generally adopted for a series of years; it consists of driving into every tie, when laid, a nail, bearing, impressed on its head, the date of such laying. We cherish the hope that the number of roads will be small that will wait for the results reported at the expiration of the second period before being convinced of the advantages of impregnation, and the great saving in the maintenance of railroads effected by this process.

Note.—The table referred to was not in the translation, but the information has been obtained from another source.

At the Technical Convention of the German Railway Union, July, 1884, a report on preserved sleepers was presented, which was supplementary to a previous report published some years ago. Of the railways answering the circular of inquiry sent out by the committee, 34 use preserved sleepers now, against 24 in 1868. The number of railways using each of the methods of preservation in 1865, 1868, 1878 and 1884 was:

	1865.	1868.	1878.	1884.
Sulphate of copper	15	6	5	1
Sulphate of iron and zinc	1	..	..	..
Sulphate of barium and oxydul of iron	2	..	..	..
Corrosive sublimate	3	6	8	4
Chloride of zinc	8	7	20	22
Creosote	4	5	13	11
Chloride of zinc and creosote mixed	..	..	4	7
Vapor of creosote (Paradis' patent)	..	..	..	1
Vapor of creosote and creosote (Blythe's system)	..	..	1	1
Antisepticum under pressure	..	..	..	1

Thus sulphate of copper, which was the prevailing method used in 1865, is now used by but 1 railway; but the use of chloride of zinc has extended until it prevails, and, alone or in combination with creosote, is used by 29 out of 48 railways which use any preservative. Creosote alone, however, is still extensively used, though less so than in 1878.

APPENDIX No. 7.

Report of M. Alexander, Esq., Roadmaster and Engineer Chicago, Rock Island and Pacific Railway.

Blue Island, Ill., March 23d, 1882.

H. Riddle, Esq.,
Pres't C., R. I. & P. R'y.

Dear Sir,—In reply to your letter of March 15th, asking for dates, etc., regarding ties that have been subjected to different kinds of treatment and laid in track on the C., R. I. & P. R'y, I can only give you the results of two lots of ties that have been treated, one of which was Burnettized and the other creosoted.

November, 1866, we laid in main track just west of Englewood about 2 000 soft-wood ties, consisting of pine, tamarack and cedar, but the greater portion of them were hemlock. These ties were all treated to a solution of chloride of zinc, and have sustained a very heavy traffic.

They are laid in a fine gravel ballast, and have received just the same attention that ties have on other parts of the road.

I made a careful examination of these treated hemlock ties last summer, and found at least 75 per cent. of them still in the track, and, in my opinion, in such a state of preservation that they will be serviceable for two or three years longer. Some five or six of these ties were taken out of track and found to be sound and solid in the center, and only decayed to the depth of $\frac{1}{2}$ to $\frac{3}{4}$ of an inch on the surface and sides. The rail has not worn into these hemlock ties to any greater extent than would have occurred with oak, and they hold a spike fully as well as the oak tie. The pine and cedar ties that were Burnettized at the same time have worn out in the 15 years' service, and have disappeared. The tamarack have held out about the same as the hemlock.

My experience is that untreated hemlock ties decay first in the center, or heart, when the spike becomes loose, and the tie crumbles; but these treated ties are sound in the center, which shows that where the chloride of zinc is not washed out the wood is in a perfect state of preservation.

In 1872 we laid in second track, east of Washington Heights, about 5 000 hemlock ties that were subjected to the creosoting process. These ties, I do not believe, were thoroughly treated; they seem to be tolerably sound at the bottom, but are badly decayed on the surface, and the rail wears into them to a much greater extent than it does into those that were treated with chloride of zinc. There is probably not more than from 30 to 50 per cent. of these creosoted ties now in track, and these will no doubt all be taken out this season.

I find that the natural life of a hemlock tie, laid in sand or gravel ballast, does not exceed five years; but if thoroughly treated with chloride of zinc, I believe they will last at least fifteen years. The creosoting process, if thoroughly done, will no doubt double the service of soft wood ties.

For any further information I would refer you to M. Lassig, who was in the employ of L. B. Boomer in 1866 and 1867, and who had charge of his Burnettizing works at that time, and subjected large quantities of bridge timber to treatment.

Respectfully yours,

(Signed) M. Alexander.

APPENDIX No. 8.

Burnettizing on Lehigh and Susquehanna R. R.

Brooklyn, April 24th, 1883.

O. Chanute, Esq.,
Chairman Committee on Preservation of Timber.

Dear Sir,—Soon after receiving your circular asking for information regarding "preservation of timber" I went to Mauch Chunk, and calling upon Mr. Twining, Roadmaster of the L. & S. Division of the C. R. R. of N. J., he very kindly accompanied me to a portion of his track in which were a quantity of Burnettized ties which have been in the track since 1867 and 1868.

The track in which these ties are laid runs along the river bank, and is in a side-cutting, in rock principally.

The ties in question consist of maple, beech and hemlock. They were mixed indiscriminately with untreated ties at the time of laying, with one, two or three in a place. With a few exceptions they have resisted decay almost perfectly. The rails have worn into them from one-fourth to five-eighths of an inch.

The beech ties that were treated had stood well, showing very little, if any, decay; but being straight-grained, they had, in some cases, split through the heart, beginning at one end, which was open from 1 to 3 inches, and extending half or two-thirds of the length of the stick.

The effect of treatment upon the hemlock ties appeared to be the best of all. They were very hard to cut, dulling the knife, and where cut presenting a glassy appearance. They were generally much harder and, consequently, less worn by the rail than any of the other woods.

Most of the treated ties in the track appeared good for 7 or 8 years longer. A few of the treated ties had been taken out of the track and piled alongside, but many of them apparently were removed unnecessarily. In nearly all cases the under sides of these ties appeared like new timber.

As an experiment, the value of the operation was greatly vitiated by mixing these ties with untreated ones, in such a manner as to render it difficult to ascertain the effect of the treatment in promoting resistance to wear under the rail.

I also examined some creosoted * cypress ties which were laid in the track of the C. R. R. of N. J., near Bound Brook station, in the year 1876, several hundred feet of track being laid exclusively with ties thus treated. They are sound, very slightly worn, and will no doubt serve a good purpose for several years longer, probably 10 or 12 years.

These ties can easily be found in the track, both from their blackened appearance and by the odor.

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* Virginia pine.—E. R. A.

The Burnettized ties can be picked out from among the others by the somewhat weather-beaten appearance of the surface, as well as from the fact that an end of each was stamped with figures showing the date at which they were laid in the track.

Respectfully yours,

L. L. Buck.

APPENDIX No. 9.

Burnettizing on Havre de Grace Bridge.

Havre de Grace, March 18th, 1882.

O. Chanute, Esq.

Dear Sir,—I have your circular of the 15th, in regard to preservation of timber. All of the timber used in the first building of the Susquehanna bridge at this place was Burnettized. I have no experience with any other process, and no experience of any kind with treatment of cross-ties. I give you copy of report made to me in 1866 by the superintendent of the works as regards the Burnettizing process. "The process of Burnettizing is as follows: The timber to be operated on is loaded on trucks, run into cylinders on the railway track, and the heads of the cylinders are closed and securely bolted. Then a vacuum is obtained by the air-pump, and maintained until the sap and impurities of the wood are extracted, a period varying from 20 minutes to 2 hours, according to the dimensions and kinds of timber. At the expiration of this time a diluted solution of chloride of zinc is let in from the tank below the cylinders. This occupies about 15 minutes. When full the force-pump is applied, and a pressure of from 100 to 150 pounds to the square inch is obtained, and kept on from 1 to 4 hours, the time depending as before upon the dimensions and kind of timber.

"By the two (2) cylinders from thirty thousand (30 000) to forty thousand (40 000) feet, b. m., of timber can be Burnettized in a day. The chloride was all made under the immediate supervision of a skilled agent of the railroad company in order to insure a reliable article. The strength of the diluted solution used was one and twelve-one-hundredths ($1\frac{12}{100}$) pounds of concentrated solution to one hundred (100) pounds of water, or about eighty-five-one-hundredths ($\frac{85}{100}$) of an ounce to the cubic foot of timber prepared." I also give you a copy of letter to C. H. Latrobe, Esq., on March 6th, 1882.

"I have yours of March 4th this evening. The weight as measured by Burnettizing is about 8 per cent., and this increase remains after seasoning. The durability, as against ordinary decay, is wonderfully increased. I have about my place a large quantity, Burnettized as long ago as the early part of 1866 (some of it probably a year or two earlier

than that). A shaving taken off with a penknife reveals clear, bright timber. I think I can safely say that I have yet to see the first piece of decayed Burnettized timber. The strength, as against cross-strains, is reduced at least 10 per cent. (probably more), against strains of extension or compression I do not think it is injuriously affected.

"The injurious effects were especially noticeable in the bottom chords, where, as is usual with the Howe truss, the floor beams rested on the chords. No evidence of weakness was discerned in braces or top chords.

"The difference in the break of Burnettized and non-Burnettized timber is such that I could, in every case, and certainly and speedily, without considering the difference in color, distinguish the one from the other.

"The breaks would be about as follows:

"1. In Burnettized timber it would be in an abrupt, ragged line, nearly directly across the stick of timber.

"2. In the non-Burnettized timber it would be in a long, very ragged line, running more or less diagonally across the stick of timber, showing much less brittleness of fiber. A piece of timber not Burnettized may break like number one, but a piece of Burnettized timber will never break like number two. These statements refer to pine timber and are the results of very careful experiments and of observation extending over sixteen years."

Yours respectfully,

EDWARD LARKIN.

APPENDIX No. 10.

DESCRIPTION OF THILMANY PROCESS.—AMERICAN WOOD PRESERVING WORKS.

DEFIANCE, O., Sept. 10th, 1882.

We have preserved all dimensions and all kinds of timbers. In Milwaukee mostly pine and oak for paving blocks and bridges and building timbers.

In Defiance we use for railroad ties all soft timber, as elm, ash, maple, sycamore, etc. We preserved all dimensions from paving blocks 6 inches high and 3 or 4 inches thick up to timbers 40 feet long, 20 x 24.

We prefer green timber; dry timber has to be steamed much longer. Only live and sound timber can be preserved.

DESCRIPTION OF THE PROCESS.

The timber is run on flat cars into a cylinder 6 feet in diameter and 80 feet in length. Steam is applied, which thoroughly drives out the sap. A powerful air-pump, connected with the cylinder, is set in opera-

tion, for the double purpose of extracting the condensed steam contained in the timber and of exhausting the air to form a vacuum. The cylinder is then filled with a solution of sulphate of copper or sulphate of zinc, and, by means of a force-pump, a pressure of 80 to 100 pounds to the square inch is applied. This pressure is kept up until all the pores of the wood are charged with the solution.

Now comes the most important point of the process, namely, to change soluble sulphate of copper or sulphate of zinc into an insoluble salt of sulphate of baryta.

For this purpose, the boiler is filled the second time with a solution of chloride of barium, and the same pressure as before applied. By means of this pressure and chemical affinity between the sulphate of copper or sulphate of zinc and the chloride of barium, a chemical combination takes place, forming the above described insoluble salt of sulphate of baryta and chloride of copper or chloride of zinc, which fills the interstices of the fiber, petrifying the pores, while a part of the chloride enters into a combination with the organic substances of the fiber of the wood. The timbers, being thus thoroughly impregnated, are now ready for use.

We have used a solution of 1½ per cent. blue vitriol and 1 per cent. of chloride barium. We have found this solution (the same as used in Europe) satisfactory for the preservation of pine and white oak timber, but not sufficiently strong for timbers growing in a swampy country, as, for instance, the timber near Defiance. It seems to me that this kind of timber contains too much condensed steam (after steaming), on account of the swampy growth, and, therefore, the solution entering the pores will be much weakened. Therefore, we use now a 2 per cent. solution of blue vitriol and 1½ per cent. chloride barium, but I would recommend, where sulphate of zinc is used, to take a 3 or 3½ per cent. solution.

The time occupied is different and depends upon the size of the timbers. For railroad ties it takes 12 hours; for larger timbers it requires more time.

We had excellent tests for preserved timber for use in breweries, as will be shown by the following letter of one of the proprietors of the largest brewery in the United States:

OFFICE OF PHILIP BEST BREWING COMPANY,
MILWAUKEE, WIS., February 18th, 1880.

Mr. A. E. BARTHEL, Detroit, Mich.

DEAR SIR,—In answer to your letter of February 14th, inst., in regard to the Thilmany process for preserving wood and timber, I can but honestly inform you that said process is a success.

We have at our city several blocks of streets and approaches to bridges paved with wood thus preserved, and find that after several

years of hard usage the wood is tougher than it was in its unpreserved state. We cannot detect any rottenness whatever. Last fall we put about six blocks of street in the Fifth and Eighth wards. These observations influenced our firm to have all timbers, heavy joists, planks and flooring needed at our new ice-houses, and for other purposes, to undergo the Thilmany process, regardless of the difference in cost. Five years ago we had the ceiling at our South Side brewhouse constructed of wood thus impregnated, and find joists and ceiling floor in as good a condition as when put up. Heretofore we had to replace same ceiling made of natural wood almost every three years, owing to the dampness and cold and warm vapors produced in a brewhouse. The wood not impregnated but painted went to a quick rot and decay.

Hoping this information will be to your satisfaction, I have the pleasure to remain,

Yours respectfully,

EMIL SCHANDEIN.

Soft timber would be considerably hardened by this process.

The city of Milwaukee has used prepared timber in large quantities for pavements, water boxes, etc., and the Board of Public Works of said city could give valuable information about this process. As said before, we would recommend the use of zinc for railroad ties, and we are willing to make a contract with railroad companies who are willing to pay such a price (25 to 30 cents a tie for preserving), that a solution of 3½ per cent. can be used, to guarantee 80 per cent. of the preserved ties for a period of 12 years, and to give the necessary security.

O. THILMANY.

APPENDIX No. 11.

DESCRIPTION OF THE WELLHOUSE PROCESS.—ST. LOUIS WOOD PRESERVING COMPANY.

ST. LOUIS, August 8th, 1882.

O. CHANUTE, Esq.,

Chairman of Committee on Wood Preserving, American Society of Civil Engineers.

DEAR SIR,—Your favor of June 3d, 1882, received and noted.

I consider wood thoroughly creosoted superior to all other for outdoor purposes where the wood has to sustain no considerable wear, or transverse stress, such as piling, foundation plank or timber laid in the ground.

But the question is, is it practical to thoroughly creosote green or partially seasoned timber, such as is used on our American railways, without injuring the wood fiber, in preparing same to receive the oil.

The treatment of wood, either with oil or a mineral salt, is of little value in my opinion, unless the material used is injected throughout the wood.

Should oil be used and not be injected throughout the entire wood (as at St. Clair Flats by the Seely process, and on the Chicago, Rock Island & Pacific Railroad, same process), little or no benefits would be derived; but had a mineral salt been used, and a sufficient quantity injected to have preserved the timber, or ties, even though at time of treatment the solution had not extended throughout the entire wood, it would, within a few days, or short period of time, have equalized with the moisture throughout the wood, which would not be the case with oil.

In my opinion, when oil is used, say in such wood as cypress (which when in condition to be thoroughly treated will take from two (2) to four (4) gallons of oil to the cubic foot), should a less amount be used than is necessary to treat the wood throughout, the result would be to preserve that portion of the wood throughout which the oil penetrated, leaving the remaining portion in worse condition than before treatment.

If it were possible to inject the oil thoroughly throughout the wood, and then remove a portion of same, it would answer well; but it is impossible to treat wood throughout with oil without injecting into said wood all it will take.

I consider that timber first injected with a mineral salt, such as chloride of zinc, and subsequently with creosote, is superior in every respect to fully creosoted wood, for the following reasons:

So far as my experience goes, it is impossible to remove sufficient moisture from green or partially seasoned wood to thoroughly creosote same, without materially injuring the fiber of the wood, which, for railway ties or bridge timber, is a serious objection.

By first injecting into the wood the chloride of zinc, and then removing the moisture from the outer portions, you can, without subjecting the wood for a long period of time to excessive heat, inject throughout said outer portion oil to the depth of one-quarter (¼) to one (1) inch or more, thereby securing all the benefits derived from the oil, where the tie or timber comes in contact with the ground, as well as insuring the thorough treatment of the wood throughout with the chloride of zinc, which is protected by the oil surrounding it, thus preventing its being chemically changed or washed out.

At St. Clair Flats, wood treated by the Seely process, which was not creosoted throughout, rotted at the heart, the surface remaining perfectly sound.

On the Rock Island Railroad, the Burnettized ties remained sound

at the heart, but decayed at the surface where they came in contact with the ground. Imperfectly creosoted ties on same road remained sound at the surface, but rotted at the heart.

Now I claim that if said ties or timber had been treated by the zinc-creosote process, they would have remained sound throughout.

It costs about seventy-five (75) per cent. less to treat by the zinc-creosote process than to fully creosote, and I am satisfied much better results will be obtained, on account of the certainty of impregnating the wood throughout with the mineral salt.

With reference to the zinc-tannin process, as practiced here :

We steam our wood three (3) hours or more, according to the diameter of the timber. We use chloride of zinc, one and ninety-one-hundredths (1.90) per cent. strong, glue and tannin, injecting the chloride of zinc and glue at same time, afterward subjecting the timber to a bath of tannin under pressure. Our object in injecting the glue with the zinc is to destroy all the tannic acid that may be in the wood. At the same time we precipitate a portion of the glue, thereby forming an insoluble leathery substance for which the chloride of zinc seems to have an affinity.

Afterward, with the bath of tannin, under pressure, we precipitate that portion of the glue remaining in the outer pores of the wood, thereby retaining in the wood a greater per cent. of chloride of zinc than would remain if simply Burnettized, as we have ascertained by experiment.

H. W. Scheffer, analytical chemist, this city, under date of October 14th, 1879, says : "The oxide of zinc has been determined directly, while the chloride was only calculated, on account of the impossibility to wash the chloride out of the chips. I have come to the conclusion that it is either retained by the woody fiber, or has formed an insoluble compound which prevents its extraction by water. The gelatine and tannin could not be determined on account of want of material ; however, tannin was found present in the watery solution, which in itself excludes the presence of gelatine."

Chauvenet & Blair, chemists, under date of June 19th, 1880, say : "Samples of wood left us, after being reduced to shavings, were boiled with three successive portions of water, in all three hours. Being then dried and analyzed, they yield chloride of zinc eight hundred and twelve thousandths (0.812) per cent."

Brandt V. B. Dixon, chemist, June 10th, 1880, says : "After boiling fine glass scrapings four hours, the water showed no trace of zinc. After drying assayed three hundred and eighty one thousandths (0.381) per cent. zinc-chloride."

The timber as we receive it here takes, per cubic foot, about as follows, viz.: Cypress, gum, white pine and other like woods, from one and a half ($1\frac{1}{2}$) to two (2) gallons of solution ; cottonwood and elm, say

three to four (3 to 4); black oak, one (1) to one and one-half (1½); white oak, one-half (½) to three-quarters (¾); yellow pine, hemlock and mountain pine, from one and a half (1½) to two (2) gallons.

Our method of injection is by pressure after steaming. Time occupied, from nine (9) to twelve (12) hours.

We have treated, say one hundred and fifty thousand gum and black oak railway cross-ties, besides some fifteen million feet of bridge and other timber.

The St. Louis Wood Preserving Company's charges for treating timber by the zinc-tannin process are eight dollars ($8) per thousand feet, b. m; railway ties, twenty (20) to twenty-five (25) cents each.

Our principal business is with the railroad companies (bridge timber, ties and the like).

We have treated gum wood, which has now been in the ground nearly four (4) years, that is as sound to-day as the day it was cut. If not treated, would show signs of decay in less than ninety (90) days, under similar conditions.

Our treatment hardens the timber, and our aim is not to affect the strength.

The ties heretofore mentioned are sound in every respect, while many untreated white oak ties, laid in same track at same time, show unmistakable evidence of decay.

I am convinced that ties treated by the zinc-tannin process will in most kinds of soil wear out before they will decay. I would not recommend the zinc-tannin process when timber or piles are submerged in water, not through any fear of its being washed out, but on account of the impurities in most water, which in time may transform the chloride into a non-antiseptic.

With regard to the treatment of wood by the Boucherie process, and by absorption:

My belief is that it is not possible to treat most, if not all kinds of wood, by either of these processes, when the wood is dry or partially seasoned.

I am satisfied that in order to treat successfully by the Boucherie process it is necessary to treat the timber at such seasons of the year as sap is flowing, and immediately after its being cut; otherwise the sap will solidify in the pores, and prevent the penetration of the solution used.

In case of Kyanizing, it would be necessary to take the wood immediately after being cut, and while full of moisture, to enable or admit of the equalization of the salt used, with the moisture throughout the wood. Should it be dry or partially so, the air within the wood would prevent contact of the solution and moisture, which is necessary in order that they may equalize. On the other hand, after steaming and vacuum, the wood is expanded, fiber softened, the gummy portions of the sap dis-

solved, made liquid or driven out, and the air expelled, leaving the wood in condition to receive the solution readily, and without obstruction, which would not be the case if treated by the Boucherie process, by Burnett's, as I understand it was practiced at Lowell, or by absorption, except in the latter case possibly by many weeks of immersion.

I send you, by express, a cross-section of each of the following, viz.: a seventeen (17) inch cypress pile, a twelve by twelve (12×12) square pine timber, an oak railway tie and an ash stick, all treated by the zinc-creosote process.

Trusting I have answered your inquiry in full, without being tedious, I remain

Respectfully yours,

Jos. P. Card,

President.

APPENDIX No. 12.

Description of the Gypsum Process.—American Wood Preserving Company.

St. Louis, November 3d, 1883.

O. Chanute, Esq.,

Chairman Committee on Preservation of Timber.

Dear Sir,—Your circular on "Preserved Timber," having reference to a selection exhibited at the National Exposition of Railway Appliances at Chicago, was handed to me only a few days ago by a friend, and naturally interested me very much.

Our company has lately purchased the creosoting works of the former Western Wood Preserving Company, and having acquired the patent of E. Hagen for treating wood with tincture of zinc chloride and gypsum in one solution and charge, we now apply this process to railroad ties, car-roofing and siding, etc., successfully, passing all lumber to be worked after the treatment through an excelsior drying kiln (Curran & Wolff) in order to season it perfectly.

We claim that by our combination of gypsum with the tincture of zinc chloride a crystalline covering of the fibers of the wood throughout will prevent the washing out of the chloride and thereby do away with the main objection so far made to this excellent antiseptic.

Since our process is quite young yet, we, of course, have no other proofs to substantiate our above claim than the testimonials of chemists, and I take the liberty to call your special attention to the one of Prof. C. Gilbert Wheeler, of Chicago, copied in our pamphlet, which I mailed you to-day.

We submit also the following certificate of analysis:

WASHINGTON UNIVERSITY,
MINING AND METALLURGICAL LABORATORY,
ST. LOUIS, MO., October 11th, 1883.

GENTLEMEN,—The samples of preserved wood from the American Wood Preserving Co. marked Cypress No. 5, Yellow Pine No. 9, Black Oak No. 13, submitted to me for examination, yielded when treated with hydrochloric acid:

	Cypress.	Yellow Pine.	Black Oak.
Chloride of zinc..	0.078 per cent.	0.096 per cent.	0.065 per cent.
Sulphate of lime..	0.360 "	0.250 "	0.232 "

Determinations made after charring wood at low temperature gave for sample as received :

	Cypress.	Yellow Pine.	Black Oak.
Chloride of zinc..	0.310 per cent.	0.249 per cent.	0.279 per cent.

This shows that even hydrochloric acid is not capable of extracting the zinc from the wood to any considerable extent.

A weighed portion of the borings from the different woods was digested in distilled water for 48 hours and the water was found to be free from zinc and lime, showing that none of these substances was dissolved from the wood. They appear to be practically insoluble in water as they exist in these samples of wood.

Respectfully,
WILLIAM B. POTTER.

Knowing that Prof. N. T. Lupton, of the Vanderbilt University at Nashville, Tenn., is recognized all over the Southern States as one of the most eminent analytical chemists of the country, and that his opinion, if favorable to our process, would have great weight, we sent him several specimens of wood of the same treatment as above, and we received from him the following certificate of analysis:

VANDERBILT UNIVERSITY,
CHEMICAL LABORATORY,
NASHVILLE, TENN., October 29th, 1883.

The samples of wood from the American Wood Preserving Co. have been carefully examined, with the following results :

	Cypress.	Black Oak.	Yellow Pine.	Cot. Wood.	Hard Gum.
Moisture expelled at 210° to 215°..	12.37 p. c.	11.98 p. c.	12.02 p. c.	12.11 p. c.	11.94 p. c.
Metallic zinc.....	0.096 "	0.070 "	0.087 "	0.083 "	0.076 "
Equivalent to zinc chloride	0.199 "	0.145 "	0.161 "	0.172 "	0.158 "
Lime as sulphate.	0.400 "	0.224 "	0.336 "	0.252 "	0.312 "

Weighed portions of the different kinds of wood were subjected to the action of distilled water with frequent agitation for three weeks, without giving the least evidence of the solution of the zinc and lime salts, with which they are impregnated.

The above determinations were made from sawdust, obtained by sawing entirely through the specimens examined. The zinc and sulphate of lime permeate the wood completely, and seem to be in the best condition possible for exerting their preserving qualities.

Very respectfully,
N. T. LUPTON, Prof. Chem.,
Vanderbilt University.

An expression of your opinion in regard to our treatment would be highly appreciated, and if your association should find it of sufficient importance to closely inspect and analyze it, I shall be very glad to send you samples of any kind of wood within our reach you may designate.

Hoping to be favored with an early reply, I am,

Yours respectfully,

THEO. PLATE,
President.

APPENDIX No. 13.

CREOSOTING ON NEW ORLEANS AND MOBILE RAILROAD.

NEW ORLEANS, LA., June 20th, 1885.

O. CHANUTE, Esq.,
Chairman Committee on Preservation of Timber.

DEAR SIR,—The line of railroad between New Orleans and Mobile runs parallel to and near the coast, crossing various arms of the sea, and so near the mouths of rivers that the tide ebbs and flows a considerable distance above the railroad crossings. The salt water flows over the bar at high tide, and at the ebb the fresh water, being lightest, flows over the top, leaving a basin of salt water in which the *teredo navalis* finds some of his choicest feeding grounds. As the tidal rise is only a foot or two, the tidal currents are not very strong. It often happens that piles driven for these bridges will be honeycombed from five to forty feet below the surface of the water, while not a sign of the *teredo* can be found at the surface.

In the construction of the road the bridges over these waters were built of unpreserved piles and timber. Before the road had been fairly completed it was found that the piles were being rapidly destroyed by the *teredo*, and before trains had been running six months a part of the bridge over Bay Biloxi gave way, precipitating the locomotive and part of the train of freight cars into the bay. Realizing that something must be done to protect the piles, and knowing of no method of reliably treating them, it was decided to sheath them with metal. Between four and five thousand piles were sheathed, part with yellow metal, such as is used for covering ships' bottoms, and part with zinc, with a layer of felt underneath. Four or five hundred were charred and oiled, and as this was less costly than covering with metal, more piles were thus treated subsequently.

The zinc corroded rapidly, and in about three years there were many small holes through it. It served as a partial protection until the bridge was rebuilt with creosoted piles, eight years later. The felt underneath did good service after holes came in the zinc. The yellow metal was

more durable and did not show many holes for six years. When taken off in eight years many sheets had lost all toughness and broke like plates of glass. The charred and oiled piles were about as durable as zinc. In charring timber, there are narrow lines or strips of clear wood between the coals, and into these, as well as places where the coal gets chafed off, the marine animals enter. It appears that there is great differences in the durability of metals in different waters, owing to the ingredients leached out of the earth and brought down by the streams. In some harbors sheet copper is reported good after forty years' service, while in others it will be destroyed in five years.

An outline history of the use of timber on the New Orleans and Mobile Railroad will apply to most roads in the South that have used the same kinds of timber.

A large amount of long-leafed yellow pine and quite a quantity of cypress was used in the construction of the road in the years 1869–70. In the year 1874 extensive renewals were required. In 1875–76 still more extensive renewals were demanded.

The decay was so rapid, especially with the horizontal timber, that in the last bridges rebuilt in 1879 probably not more than 5 per cent. of the original pine stringers and caps remained. But some of these were sound and would probably have lasted two or three years longer. Some of the timber which had been put in to replace that which first decayed had become so rotten as to require renewal.

The cypress was much better than the yellow pine, and estimating from recollection, I think that not more than 25 per cent. of the cypress had been removed on account of decay. Black cypress is much the most compact, heavy and durable of any kind that I have used. The red comes next, while the white cypress is but little better than good yellow pine. For cross-ties it is not as good, except in straight track, being too soft to hold the spikes and rails.

I think through the Southern States, where there is a long, warm season favorable to fermentation and decay, yellow pine may be expected to last from five to ten years, and red and black cypress from ten to twenty for ordinary trestle bridge work where kept up free from the ground. There is little timber other than pine and cypress suitable for bridge work in this section of country.

In 1875 it was decided to rebuild all the bridges on the road with creosoted piles and timber, under the supervision of the writer, who had been investigating the subject for two or three years. Quite a number of parties were creosoting timber for various purposes, and at first it was thought practicable to contract with them for the required material. Examination of their products and of the oldest creosoted work that could be found convinced the writer that if creosoting could be properly done, it would be good and effective; but if it could not be better done than any one was then doing it, it had better be let alone. Paving

blocks, planks and piles were being treated under various patents, but always with oil at a potency that would make glad the heart of a high dilution homeopathist. By their peculiar methods of doing business they drove from the field and almost out of use the best and most durable kind of paving for driving and ordinary street wear that has ever been laid. It is noiseless; it is elastic under foot, so that horses can endure speed and service; it is not slippery, and therefore safe. The result, the general suspension of creosoting, might have been anticipated. Wherever a piece of timber could be found which had been saturated with oil it was perfectly sound, and these isolated specimens were the evidences that convinced him that creosote was a specific against decay and the ravages of marine animals, if properly used.

After a series of experiments plans were adopted differing considerably from anything in use. Works were constructed at West Pascagoula, Miss., and the work of reconstructing the bridges with creosoted piles and timber commenced about the first of March, 1876. The result of the first year's operations gave a consumption of 1.8 gallons of oil (equal to 15 or 16 lbs.) per cubic foot of timber treated. This included piles and sawn timber, but piles will absorb more oil than hewn or sawn heart timber. Nearly all the timber treated was long leaf yellow pine. It included piles and timber for superstructure and water-ways and culverts. Our opinion now is that for marine purposes not less than two gallons of oil should be used per cubic foot for yellow pine. For spongy, porous timber a much larger amount will be required to give an equally uniform and safe treatment. For fresh water or dry land work a less quantity will give good results, but the amount should be proportioned to the kind of timber used, solid, compact timber requiring the least. Timber should be heated through to above 212° F. (whether dry or green), and have the air and moisture exhausted, and in that condition receive the oil.

We did not gauge ourselves to any given quantity of oil per cubic foot, but endeavored to make the work as thorough as practicable. We did not thoroughly saturate through and through the piles or sawn timber, and I do not think any process is known whereby solid, compact timber of large size can be thoroughly saturated by a one or two days' treatment.

The bridge over Chef Menteur was the first to be rebuilt of creosoted timber, and this was done during the months of March, April and May, 1876. It is an iron truss with spans of 110 feet, resting upon pile piers of 16 piles each, each pile capped with a cast-iron socket, and the whole surmounted by a wrought girder pier-head upon which the truss rests.

The stringers, cross-ties and guard-rails are of wood.

All the wood-work of the bridge, including piles, was as thoroughly creosoted as practicable, having an average of nearly two gallons of creosote oil per cubic foot.

The bridges over the mouths of Pascagoula River were next built in the months of May, June and July upon the same plan.

During the summer of 1876 several small structures, culverts and water-ways were built entirely of creosoted timber, and also a sheet piling revetment along the sides of the embankment, across Lake Catharine, which is nearly a half mile long.

This revetment was built of creosoted inch plank, driven double, so as to break joints, and bearing against a wale plank or stringer, supported by piles on the outside.

During the following winter the bridge across the Great Rigolets, nearly three-fourths of a mile long, was built. The piles in these structures are subject to attacks of the *teredo navalis*, especially those at the crossing of the Pascagoula River, where piles a foot and a half in diameter have been cut off by the *teredo* in a single year.

During the summer of 1877 no creosoting was done, but during the fall, winter and spring following a great number of water-ways and trestles, and the bridge over Pearl River were built. The water in these large streams is from 15 to 45 feet deep, and piles were used from 40 to 95 feet long.

During the month of June, 1885, I examined the bridges built nine years ago. I bored a great number of cross-ties, stringer timbers and piles (always plugging the holes with a creosoted pin), selecting such as I thought most likely to show signs of decay, if any existed. Every piece of timber was in perfect order, the wood inside the line blackened by the oil being as clean and bright as when cut. The piles showed no indication of having been cut by the *teredo*.

Another suspension of creosoting occurred during the yellow fever epidemic of 1878. The work of construction was carried on during the winter following, and finished during the summer of 1879, by the rebuilding of the bridge across Bay Biloxi, one and one-fourth miles long, and across Bay St. Louis, two miles long. The deepest water here is about 15 feet, but the bottom is so soft as to require piles from 40 to 70 feet long.

Since then no organization for bridge work has been necessary on the road, as the bridges are in perfect line and surface.

The sandy country through which the road runs makes absolutely tight culverts or water-ways necessary. These have been built of creosoted timber and placed in the bank so as to allow a covering of earth of from one to twenty feet deep. Where the earth was solid enough these were constructed by using plank or timbers set edgewise, and running across the road bed. They were floored by plank extending into the bank outside the culvert walls about a foot, and covered by plank with a thickness corresponding to the width of opening. The openings vary from 1 to 12 feet in width, and from 1 to 6 feet high. They have one or more openings to suit the volume of water to be discharged.

Where the ground was soft piles were driven and capped and floored over, and the sides built of double sheet piling plank 1 inch thick, and driven to a depth to guard against washing out. For larger streams, from 50 to 600 feet wide, and the track, from 10 to 30 feet high, piles were driven, capped and floored over and covered with sand or gravel about a foot in depth, and in this was laid the ordinary embankment cross-ties to be lined and surfaced by the track men. This makes a cheap (and we think durable) viaduct, and does away with the jump or bouncing motion so often felt in passing open water ways or trestles, and protects from fire. I do not think creosoted timber half as liable to take fire as timber in the natural state.

Since then a wharf has been built at Ship Island, a foundation put under the lighthouse at Horn Island, and several pieces of work put in on the Mobile and Montgomery Railroad, and a wharf at the Mobile Depot.

Wharves have been built extensively in the Bay of Pensacola, and railroad bridges on the Pensacola and Atlantic Railroad.

Several thousand creosoted piles are in the waters of Pensacola Bay, where the *teredo* is very destructive to timber.

We have used a larger amount of oil per cubic foot of timber treated than has generally been considered necessary, but the almost universally satisfactory results confirm us in the opinion that creosoting is valuable in proportion to the amount of oil injected, and wherever a piece of timber decays or is destroyed by marine animals, it may be set down as a fact that there has been improper treatment.

The most carefully conducted experiments indicate that there is no decay without fermentation, and no fermentation without germs. If a piece of timber be cut green and thoroughly coated with paint, it will soon be destroyed by what is called dry rot. If a similar piece be heated through to 225° F., and a sufficient amount of oil be forced in to form an impervious coating, no decay will take place until that coating is broken.

Wherever that coating is broken, and the air with its dust allowed to come in contact with the unsaturated wood, decay follows and extends in each direction from the opening. It does not affect the whole mass of untreated timber at once, but commences at the opening and extends gradually, and it may be years in consuming all of the uncreosoted wood. If absolutely necessary to cut the timber after creosoting, such surfaces should be thoroughly oiled and pitched, or in some other manner protected. I do not think the "coagulation of the albumen" much of a factor in the preservation of wood. Something else must be relied on as an antiseptic. The character of wood seems to be so changed by saturation with creosote oil that the ferment germs find no nourishment, and though the oil may have become as thoroughly dried out as possible, no fermentation or decay takes place.

By the courtesy of the General Manager of the Old Colony Railroad, I have just been enabled to examine the bridge built over the Taunton River, at Somerset, in 1865. It was referred to by Chief-Engineer Winslow in 1878. Nearly all the original 700 piles creosoted have disappeared or have had another driven alongside, and are still left bolted in the bridge. Evidently the work was done in what we should now call a very superficial manner. The original "Bethell process" was used, depending solely on pressure to force in the oil, and with no provision for extracting the sap, except the traditional vacuum pump. Water cannot be drawn out of timber by simply producing a vacuum in the tank containing it. It is not forced in by atmospheric pressure, but by capillary attraction, which remains the same after the air has been exhausted. Neither can it be removed by ordinary steaming, as that only carries more moisture to the wood. The piles were green, and generally treated with the bark on. In creosoting, the greater part of the oil is absorbed through the side of the timber, and not by flowing along the pores. The bark, being spongy, absorbed more oil than the green wood, and acting as a strainer, retained the densest and best part of it. When, therefore, the bark fell off, which it was sure to do, the piles were left poorly protected. That part of the pile which received oil twenty years ago is as sound as when cut, though the interior may be rotten. The piles apparently have lasted much longer than they would had they not been creosoted.

A few piles were used around the draw-bridge that were not creosoted. The bark was relied upon for protection, and in places where the bark was off or where trimming was done, nails were driven in near together, and, I think, a cloth or something of that kind was laid on the wood, though I could not ascertain positively. At any rate, all such places that I saw, which had been below the water line, were sound and free from attack by the teredo. Some such patches were left above the water, the piles probably not being driven as far as anticipated, and in these the nails had completely oxidized, so that they could be dug out like sand, and the wood between the nails, which were about half an inch apart, was also destroyed, being as brittle and easily dug out as charcoal, while the surface of the wood around these places and out of the influence of the iron was quite good. The difference of the effect of the nails above and below the water line was plainly seen.

Some hemlock cross-ties were creosoted and laid in the track near the creosote works about sixteen years ago. They had been hewn and were more or less seasoned, and received a goodly quantity of oil. The oil has become dry and hard on the outside, but inside it is yet limpid and may be squeezed out, after removing the outside of the tie. I could not learn as a single tie had been removed for cause, and they with others of later date are doing service. Some other pieces of hemlock and spruce were creosoted and cut up for other use. Wherever the oil

penetrated, the timber is perfectly sound, though the center may be soft and rotten. The creosoted part is as tough and fibrous as ever.

I do not think the fiber of timber is ever made short or brittle by creosote, though it may be, and sometimes is, by overheating. I do not think timber should be heated to more than 250° F.

It has generally been considered that palmetto or cabbage wood was safe from the attacks of marine animals. I found several pieces at Pensacola, three or four years ago, which had been more or less eaten. This summer I saw at Charleston, South Carolina, numerous pieces badly eaten. They were taken out of a wharf, at the Custom House, which was being rebuilt. I sent samples to the rooms of the Society at New York. In some of the pieces the teredo seemed to be well fed and flourishing, measuring about half an inch in diameter.

With ordinary timber the bark is a protection against the teredo, but with the palmetto that seemed to be the choicest part, though they cut both wood and bark. The wood of palmetto seems to be a bundle of interlaced fibers, held in place by a kind of vegetable cement, which dissolves when the timber is used under water, and the fibers can then be drawn out singly. It has but little strength in either direction. Its greatest strength is in the bark.

Respectfully yours,

J. W. Putnam.

APPENDIX No. 14.

Remarks on Creosoting.

Octave Chanute, Esq.,

Chairman of the Committee on Wood Preservation.

Dear Sir,—My own practical experience in wood preservation has been confined to creosoting. In England, where the metallic salt processes, *i. e.*, Kyanizing, Burnettizing, etc., started in the race with creosoting about the year 1838, creosoting alone survives, and has been generally adopted wherever wood is used in railroad construction or other out of door work. Before engaging in creosoting as a business, I satisfied myself, through European correspondence mainly, that properly creosoted wood is indestructible by marine animal life, and will resist decay almost indefinitely. The members of our Society were at that time generally unfamiliar with the process and inclined to be skeptics. Since then sufficient has been learned from actual experience in this country to confirm the good reputation of this process in Europe.

In some of our earlier transactions are papers giving results of experiments in so-called creosoting, especially as regards its efficiency in preserving timber from the *teredo.** The fact is that it was not creosoting

* Trans. Am. Soc. C. E., Vol. III, paper No. XCV; No. CXXXI, Vol VI, page 189.

at all, but a pretense. Mr. C. B. Sears says : "Over 1 000 000 of feet was treated by the 'Robbins' process, a modification of the Bethell ; it was impregnated * * * * with the vapor of hydro-carbon oil, about 1¾ lbs. of oil to the cubic foot, and cost $10 coin per 1 000 feet, b. m." This in California.

That such creosoting failed is no wonder, yet it served to prejudice the process.

The first really valuable information on wood preservation in the possession of the Society is the paper of the Secretary, John Bogart (on Permanent Way ; Trans. A. S. C. E., Vol. VIII, January, 1879). This paper gives, in tabular form, without comment, categorical answers to a series of questions, asking for actual experience, obtained from an extended correspondence with the chief engineers of all the large railways in Great Britain. From that date the subject of wood preservation has been frequently discussed at our annual meetings, and several valuable papers thereon have appeared in our Transactions.

As stated above, the early creosoting was very imperfectly done, and generally by companies started with large paper capital for the purpose of selling stock. Creosote was expensive, and the methods adopted by these companies were efforts to dispense with the use of creosote, except in a vaporous state. In two or three places works were erected to carry out the Robbins vapor process, but there was little business and less faith. This failing, an attempt was made to adapt the weak machinery to good (?) creosoting. The cylinder burst at a pressure of 10 lbs. These attempts were followed by a period of distrust, and later came the creosoting of the present day, with expensive, powerful and efficient machinery, and a system of thorough treatment, which, in some respects, is superior to the English system, and will give good results.

There are three essentials to success :

1st. The selection of suitable varieties of timber.

2d. Proper dessication.

3d. The injection of a sufficient quantity of creosote.

First.—It is safe to say that the varieties of timber which are the most perishable without treatment are best suited for creosoting. They are absorptive ; without treatment they readily take in from their surroundings the seeds of decay, and under treatment they absorb the creosote freely and evenly. Where such wood will be subjected to strains, the engineer must call for larger dimensions than he would use with denser and stronger woods. But such allowances made, the Virginia or North Carolina pine is far better for creosoting than the Georgia pine, and porous black or red oak than white oak, and in either case the more sap wood the better, as the sap wood is always fully saturated. Spruce is unreliable for the purpose, on account of the diversity in density in different specimens. The most conscientious treatment of spruce will fail to obtain uniform and reliable results.

Second.—Dessication.—The Bethell process in use in England requires that all timber intended to be creosoted shall be exposed in the air until fully seasoned. In this country, when any important contract requiring timber is awarded, the trees are still standing in the forests. There is no available seasoned timber. Hence we are compelled to adopt artificial dessication, with the aid of steam coils within the treating cylinder, before the creosote is admitted. But, through this necessity in the American process, we secure additional preservation, because the degree of heat employed in the dessication (about 250° Fahrenheit) coagulates the albumenoids in the sap wood, and thus, in so far as coagulation acts as a preservative, all which is accomplished by the metallic salt process is attained in addition to the action of the antiseptic and other properties of the creosote itself. Without preliminary dessication, creosoting must always be disappointing in its results, as there will be many wet places unprotected.

Third.—The injection of a sufficient quantity of oil. Creosoting does not claim to be a cheap process. Its cost, and that alone, stands in the way of its general adoption. On this account, while I protest against the small doses first used in this country (from an ounce of tar vapor to 2 lbs. of oil), I yet believe that more than enough is wasteful. During the first thirty years after the introduction of the process in England the practice was to inject from 6 to 8½ lbs. per cubic foot, and the longest records of sound usefulness are of specimens thus treated ; but when the wood was to be protected from the *teredo* 10 lbs. per cubic foot were used. Eleven hundred piles driven at Leith, Scotland, in 1848, and reported by the engineer in charge as perfectly sound in 1882, were treated with 10 lbs. only per cubic foot. Later practice in England sometimes calls for 10 lbs. as a protection from decay alone, and Mr. Boulton, of London, who has had more than thirty years of practical experience in creosoting, wrote me that more than 12 lbs. per cubic foot is never called for by English engineers when for use in tropical climates.

It does seem to me that the dose proved to be sufficient in England should suffice here. The atmospheric conditions are quite as favorable to decay there, and the cutting tools of the *teredo* are quite as actively employed, the Gulf Stream maintaining a long season for their work. As a practical creosoter, while willing and able to inject from 20 to 40 lbs. per cubic foot in porous wood, if required, I feel impelled, in the interest of economy, to discourage the specification of more than 10 to 12 lbs. per cubic foot in most cases.

Creosote oil is a distillate of coal tar—a residual product in the manufacture of coal gas. Chemists have procured from coal tar a vast number of sub-products and combinations of great usefulness in dyeing, etc. The three principal coarse products of coal tar are the light oils, the heavy oils and pitch, all the results of distillation.

The light oils (lighter than water) evolve in the distillation at a tem-

perature of 360° to 480° Fahrenheit. From these all the aniline colors are made. They are expensive and have no value whatever in wood-preservation. The heavy oils (heavier than water) are distilled at a temperature of from 480° to 760° Fahrenheit. These are the so-called creosote oils, and contain all the constituents of the coal tar useful in wood preservation. After the creosote comes the pitch. Creosote contains about 5 per cent. of tar acids, *i. e.*, carbolic, cresylic and other acids, but the bulk is made up of semi-solid oils and naphthaline.

Wood preservation by the metallic salt processes is solely chemical. Earlier, it was claimed that the zinc chloride, etc., formed insoluble chemical combinations with the albumen contained in the sap wood. Now, it is generally allowed that no such combinations are formed, but that the value of metallic salts as antiseptics depends upon their continual presence in the woods, and as they are readily dissolved out of the wood their effect is only temporary. The life of wood is prolonged by their use, when skillfully applied, yet in moist places they quickly lose their efficacy.

The creosoting process is both chemical and mechanical. Besides the carbolic and other acids, it contains many other well-recognized antiseptic constituents ; but it is probable that the very long life of timber secured by thorough creosoting is due far more to the fact that the pores of the wood are filled up with the thick, gummy, insoluble oils and the naphthaline, and thus keep out air and water, which contain the germs of decay. That such is the case was conclusively shown by M. Roltier,* a Belgian chemist, and later in 1866 by M. Charles Coisne,† Chief of Section of the State Railways of Belgium and Superintendent of the Creosoting Works.

By the latter, two series of experiments were tried during a period of five or six years in burying in a compost heap made of decaying wood, manure, etc., shavings impregnated with creosotes containing different percentages of carbolic acid. The results showed that shavings saturated with carbolic alone were entirely decayed, and those saturated with the distillates at the highest temperatures which contained no carbolic whatever were perfectly sound.

Experience with the metallic salts and the results of above experiments indicate that to preserve timber something more is required than an antiseptic for the purpose of coagulating the albumen. The very small percentage of albumen contained in the sap wood probably ferments readily and may originate decay ; but the agencies of fermentation introduced into exposed timber by the air and water absorbed by the wood are vastly more dangerous than the seeds of decay contained originally in the wood itself.

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* Bulletin de l'Academie Royale de Belgique. 2me Series, Tome XVII. No. 4.

† Extrait des Annales des travaux publiques de Belgique. Tome XXII. Note sur la Construction des bois aux Moyens d'echantillons d'huiles creosotees obtenus a differentes temperatures. Ditto, Tome XXX.

During the past hundred years almost every imaginable substance has been proposed as a preservative of wood, yet it may be that inventors are still at work; if so, their attention would be best directed to such methods or materials as would close the pores of wood to air and water.

The following record of experiments made in the Harbor of New York by the Department of Docks of that city and kindly furnished by Mr. G. S. Greene, Jr., M. Am. Soc. C. E., Engineer-in-Chief of the Department, will probably prove of general interest.

EDWARD R. ANDREWS.

NEW YORK, May 10th, 1882.

DEPARTMENT OF DOCKS,
117 and 119 Duane Street.

ENGINEER'S OFFICE, CHAMBERS STREET,
Sept. 13th, 1883.

MR. GEO. S. GREENE, JR.,
Engineer-in-Chief.

SIR,—The accompanying comparative table gives the results of five annual examinations,* made by the aid of a diver, of certain pieces of wood put down in May, 1878, at the end of Pier No. 1, North River, to ascertain the effect upon them of the teredo. These pieces of wood have always been placed where the current is strongest and entirely clear of the mud line, in order to expose them to the full action of the worms, and to show as strongly as possible the value of the different means that were adopted to protect them.

The numbers and groups were as follows:

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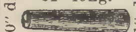
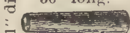
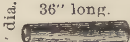
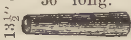
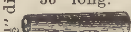
* At each examination a cross-section about 2 inches thick was cut off of one end of each piece of wood.

ALL SPECIMENS WERE IMMERSED UNDER SAME CONDITIONS, MAY, 1878.

Groups.	No in Group.	Kind of Wood and Treatment.	Size of Specimen.	Condition of Specimens when Examined. May, 1879.	May, 1880.	May, 1881.	May, 1882.	May, 1883.
No 1	1	Spruce, no nails........................	4″ × 10″ × 12″	Large number of worms.	More eaten than last year.	More eaten than last year.	More eaten than last year.	Honey-combed.
	2	Spruce, entire surface covered with carpet nails	4″ × 10″ × 12″	No worms......	No worms	No worms......	No worms......	No worms.
	3	Spruce, entire surface covered with 3d. nails	4″ × 10″ × 12″	No worms......	No worms......	No worms......	No worms......	No worms.
No. 4	10	Oak piles, no nails......................	10″ dia. 31″ long.  11″ dia.	Large number of worms.	Large increase .	Same as last year.	More eaten than last year.	Honey-combed.
	11	Oak pile, carpet nails, 35 lbs. driven about ¼″ apart......................	10″ dia. 31″ long.  11″ dia.	No worms......	No worms......	No worms......	No worms......	No worms.
No. 5	14	Pine pile, no nails.....................	11″ dia. 36″ long.  12″ dia.	30 to 40 worms.	50 to 60 worms.	Honey-combed.	Not as bad as last year.	About 180 worms.
	12	Pine pile, bellows nails, 20 lbs., carpet nails, 12 lbs., driven about ¼″ apart.........	11″ dia. 36″ long.  12″ dia.	No worms......	No worms......	No worms......	No worms......	No worms.
No. 6	15	Spruce pile, no nails....................	13½″ d. 36″ long.  14″ d.	30 to 40 worms.	60 to 70 worms..	Honey-combed.	Honey-combed.	Honey-combed.
	13	Spruce pile, 20 lbs. 3d. nails, driven about ¼″ apart, and a zinc cap on one side.	13½″ dia. 36″ long.  14″ dia.	No worms.....	No worms......	No worms......	No worms......	No worms.
No. 7	16	Spruce pile, 4 lbs. carpet nails	One worm........	One worm......	One worm......	One worm......	One worm......	No worms.
	17	Spruce pile, 5 lbs. 3d nails; nails in both No. 16 and No. 17, driven from ½″ to ¾″ apart................................	3 to 4 worms.....	9 to 10 worms..	About 17 worms	About 17 worms	About 17 worms	10 worms.

ALL SPECIMENS WERE IMMERSED UNDER SAME CONDITIONS, MAY, 1878.

Pairs.		* Kind of Wood and Treatment.	Size of Specimen.	Conditions of Specimens when Examined.				
				May, 1879.	May, 1880.	May, 1881.	May, 1882.	May, 1883.
No. 1	1	White pine, creosoted	2'.11" × 14" × 3"	No worms	No worms	2 worms	No worms	No worms.
	2	White pine, not creosoted	2'.11" × 14" × 3"	A few worms	Honey-combed.	Honey combed.	Honey-combed.	Honey-combed.
No. 2	1	Oak, creosoted	2'.3" × 9½" × 3"	No worms	No worms	No worms	No worms	No worms.
	2	Oak, not creosoted	2'.3" × 9½" × 3"	A few worms	Honey-combed.	Honey-combed.	Honey-combed.	Honey-combed.
No. 3	1	Yellow pine, creosoted	2'.2" × 10" × 3"	No worms	No worms	No worms	No worms	No worms.
	2	Yellow pine, not creosoted	2'.2" × 10" × 3"	7 worms	Honey-combed.	Honey-combed.	Honey-combed.	Honey-combed.
No. 4	1	Spruce, creosoted	2'.2" × 10" × 3"	No worms	No worms	No worms	No worms	No worms.
	2	Spruce, not creosoted	2'.2" × 10" × 3"	8 worms	A few more	Honey-combed.	Honey-combed.	Honey-combed.

* Groups Nos. 1, 2, 3 and 4 were furnished by Mr. Edward R. Andrews.

(Signed) W. W. Maclay,

Supt. of Section.

APPENDIX No. 15.

Creosoting on Houston and Texas Central Railway.

Houston and Texas Central Railway,
Division Engineer and Supt.'s Office,
Houston, April 7th, 1882.

To the Committee on Preservation of Timber,
Am. Soc. of Engrs., N. Y.

Gentlemen,—In answer to your communication of March 29th, on the subject of preserving timber, I would say that the Houston and Texas Central Railway Company has treated about 150 000 cross-ties and a small quantity of bridge and tank-frame timber with creosote, or "dead oil," in the last two years.

Sufficient time has not elapsed for the results to be ascertained on this special work, but enough is known of the effects of "creosote" in preserving similar timber in this climate for a period of eight years to give a good guaranty of success.

The timber used thus far for ties is the short-leaf "Texas pine," a porous and perishable wood, that, untreated, will not last more than two years on or in the ground, or exposed to the weather. It takes the oil freely when partially seasoned, and when entirely dry will readily take more than two gallons to the cubic foot. Our works consist of two cylinders 100 feet long, in which the timber is treated, calculated to stand a pressure of 150 pounds per square inch; a superheater, and vacuum and pressure pumps, with suitable steam power and pipe connections, and cisterns for conveying and holding the oil. The process, in brief, is, first, application of superheated steam, then withdrawal of the condensed steam and sap that may have come from the wood, and production of a vacuum by means of a vacuum pump, the temperature being maintained at the same time by dry heat from the steam pipes, and finally following with the oil at a temperature of about 160 degrees, and with such pressure as may be necessary to produce the desired results.

Our ties contain about 4¼ cubic feet, and we propose to use about 5 gallons of oil to the tie; the length of time necessary to do this depends on the condition of dryness of the ties when treated. When quite dry, very little steam is needed; in fact it might be dispensed with; 30 minutes of exposure to superheated steam and the same length of time with an oil pressure of 20 pounds are sufficient.

But if the timber is green, 4 hours use of the steam, and 4 hours of oil pressure of 100 pounds per square inch, may not accomplish the same result. In practice, the treatment is varied within above limits, according to the condition of the timber and ascertained results after treatment. Natural seasoning is much the best, and it is considered that the saving in fuel and cost of running the works, by reducing the time of treatment to a minimum, will more than compensate for the expense of cutting the

ties, say, four months in advance, which in this climate is enough to put them in good condition. An examination of a lot of ties taken out of a cylinder after treatment will show that, while the oil consumed will average, say, 1¼ gallons to the cubic foot of timber in the cylinder, some of the ties are entirely saturated, and others have received the oil only to a certain depth from the surface, leaving the heart in its natural condition; a want of uniformity to be explained only by differences in seasoning, and differences in the grain of the wood in different trees. The latter cause is a peculiarity which will probably be found incident to every variety of timber to a greater or less extent, when exposed to this test. It is not easy to secure uniformity of treatment, for, if the pressure is continued until all of the timber in the cylinder is saturated, there will be a consumption of from 7 to 9 gallons of oil to the tie, which is much more than it is deemed necessary or profitable to use in cross-ties. It is desirable to ascertain what depth of penetration of a preservative is necessary (less than complete saturation) to insure protection.

Concerning this we have the following experience: A lot of short-leaf pine ties were treated for this company and placed in the track in 1875. They were treated in double lengths and cut in two to be used; dimensions, 7″ x 9″, 9 feet long. About 10 per cent. were not treated through, and an area of from 2 to 4 inches in diameter of natural wood was thus exposed at one end to air and moisture. These ties are now all perfectly sound where the wood received the oil, but decay commenced very soon at the untreated exposed ends, and has penetrated in at that end only to an extent varying in length in proportion to the size of the area exposed. Where the surface was 4 inches in diameter the hollow extends 30 inches; where only one inch in diameter the decay reaches 11 inches.

It is fair to infer that if these ties had been treated in the same manner in single lengths there would have been no decay, and the untreated parts would now be sound.

The timber has been hardened by this process, and shows as yet no serious wear. It would have been utterly worthless in two years had it not been treated.

Failures in the use of preservatives are most probably often in consequence of failure to secure the presence of the material in the wood, as it is only by frequent and careful tests while the work is going on that one can know the character of it, and that it is being well done.

Should you desire any further information in regard to our methods of treating timber, I shall be pleased to furnish it, as far as I can. The above is an outline only, and I have suggested some points for your consideration, which I think are worthy of investigation. I will send you a treated block of the pine timber we are using.

Yours respectfully,

M. G. Howe.

APPENDIX No. 16.

The Boucherie Process in Europe.

Paris, April 10th, 1882.

W. W. Evans, Esq.,

Consulting Engineer.—Sans Souci.

Dear Sir,—You ask for pamphlets concerning Dr. Boucherie's process of preserving wood. Some twenty years ago I was much interested in this question and investigated the matter. I was led by the study of the various systems to propose a combination of the Boucherie and the so-called Bethell systems. I published a pamphlet on the subject in French and German. I send you both by this mail; but it will not be easy to find the very "antique" *brochure* of Dr. Boucherie.

I will try to give you, however, some particulars on the history of Dr. Boucherie's processes.

Dr. Boucherie's first experiments were made in 1838. He introduced by aspiration (vital suction) in the trees an antiseptic (pyrolignite of iron). He changed his views, and in 1846 he preferred to introduce the antiseptic by hydraulic pressure and to use sulphate of copper (SO_3 CuO). During the year 1839 a communication on Dr. Boucherie's process was submitted to the Academy of Science, at Paris, but till 1846 no practical application was made.

In 1850 appeared in the Annales des Ponts et Chaussées (March and April, 1850), a report on Dr. Boucherie's process.

This report says that a trial of 7 years had given very good results. In 1846 the French *chemin de fer du nord* ordered 60 000 cross-ties of oak, preserved by Dr. Boucherie's process. At this time the cost of preparing a cross-tie was very high. A cross-tie of 0.10 cubic meters in volume cost 1 franc 11.4 centimes, as follows:

	Francs.	Cents.
General expenses	0.060	1.2
Building benches	0.048	1.
Transportation of ties	0.304	6.
Sulphate of copper	0.499	10.
Workmanship	0.203	4.
Total	1.114	22.2

He used nearly 7 kilogrammes of sulphate of copper per cross-tie, of which 5 or 6 kilogrammes were absorbed, the remainder being lost.

The Austrian Railroad, to which I was attached from 1860 to 1864, used Dr. Boucherie's process to preserve white beech ties, and I had charge of this department. In a tank, about 7 meters to 10 meters high, was the solution of sulphate of copper. Pieces of round wood of the double length of the ties were partly cut in the middle and the solution

introduced in the so formed space. The wood was fresh cut, and the solution ran through in longitudinal direction.

After 10 hours' treatment the wood was considered to be prepared. The surplus solution was received in gutters and pumped back into the tank. I found that wood containing too much sulphate of copper was brittle, and perished sooner than wood containing less of this salt. I explain this by the formation of crystals which burst the fine capillary spaces in the wood. I obtained the best results by washing out the excess of sulphate of copper. The combinations of oxide of copper with albumen and resin are not soluble in water. From 1867 to 1869 I tried to preserve wood in the harbor of Trieste against the *teredo navalis* by sulphate of copper. The first 12 or 15 months this succeeded, but when all the soluble salts of copper became washed out, the sea worm could eat the wood without danger to his health, and then the wood was no longer preserved against attack. To preserve wood against the *teredo navalis* or other sea worms by sulphate of copper it must be richly impregnated, so to conserve the soluble salts, and then be covered with tar, in order to prevent the copper from washing out of it.

The great trouble with Dr. Boucherie's process is that, to employ it, wood must be freshly cut, and that it has then to be sawed into cross-ties after preparation. The first condition gives trouble in the forest, the latter increases the cost. (The steel of the saws suffers much from the copper salts.) The outer parts of the wood are not penetrated by the antiseptic salt.

I developed all this in my pamphlet. When in 1870 I had to organize the preservation of cross-ties (white beech) on another Austrian railroad, I used copper cylinders in which I prepared cut cross-ties under 7 to 8 atmospheres pressure, after an introduction of steam in order to soften the surface of the dry cross-ties. This apparatus is still working, and has prepared about 2 000 000 of ties. The price of preparation is about 35 centimes. If creosote is cheap, I consider this antiseptic as the best. To fasten the rails on cross-ties prepared with copper salts, it is recommended that we make use of galvanized nails, or make holes for the nails and introduce tar in these holes as well as on the top of the ties where the rail touches them. In Germany they use preferably chloride of zinc for preserving cross-ties.

In France as well as in other parts of Europe the Boucherie process is nearly abandoned for the reasons above stated. When I used it in the years 1860 to 1864, in South Hungary, the cost of preparing a cross-tie under Dr. Boucherie's patent was materially lower than the 1 franc 11 centimes (22 cents) estimated in 1850. I believe it could be used for about 70 or 80 centimes (14 to 16 cents) apiece.

I am, dear sir,

Very sincerely and truly yours,

E. Pontzen.

APPENDIX No. 17.

Report on Economy of Burnettizing.

New York, Lake Erie and Western Railroad Co.,
Office of the Chief Engineer,
P. O. Box 839. New York, May 4th, 1883.

R. Harris, Esq., *Vice-President, &c.*

Dear Sir,—In answer to your inquiry as to what is my estimate of the annual saving to be expected, if Burnettized hemlock ties are used instead of the present practice, I beg to report that the following table shows the number of ties annually used in repairs.

Year.	Eastern Div.	Delaware Div.	Susquehanna Div.	Western Div.	Buffalo and Rochester Div.	Totals.
1875	186 700	140 597	118 045	102 375	92 000	639 717
1876	184 110	92 930	125 945	139 426	175 555	717 966
1877	148 201	107 354	123 576	110 141	108 466	597 738
1878	112 342	104 472	153 622	106 537	129 581	606 654
1879	155 000	238 000	215 500	121 130	232 213	961 863
1880	159 799	109 954	138 204	114 645	281 124	803 726
1881	132 300	126 958	118 204	117 419	155 422	650 303
1882	170 218	132 815	61 923	87 923	266 636	719 530
	Total..	....	....	....	....	5,697 498

These renewals, for the eight years tabulated, average 712 187 ties a year, and as during that time the road was operating an average of 1 329 miles of main tracks, and of 406 miles of side tracks, there were during that time approximately 3 520 000 ties in the main track and some 1 060 000 ties in sidings, a total of 4 680 000 ties on the whole line. This, divided by the 712,187 which were replaced on an average each year, gives an average life of 6½ years each for the unprepared ties heretofore used on the road.

I believe, however, that in point of fact the average life of ties is about 5½ or 5¾ years in the main tracks, and about 8 years in side tracks, where they are allowed to remain until they are in a worse condition of decay, and where the lesser running of trains diminishes their cutting under the base of the rails.

These ties are of three kinds of timber : white oak, which costs an average of 62 cents a tie, and lasts about 7 years ; chestnut, which costs an average of 45 cents a tie, and lasts about 5 years ; and hemlock, which costs an average of 28 cents a tie, and lasts about 3½ years. To the above prices must be added some 15 cents a tie, for the cost of distributing them, and putting them in the track, so that the first cost to the road, and the annual charges are as follows :

White oak,	cost 77c.,	lasts 7 years,	annual charge	11 cents.
Chestnut,	" 60c.,	" 5 "	" "	12 "
Hemlock,	" 43c.,	" 3½ "	" "	12.3 "

All experience conclusively proves that hemlock ties thoroughly Burnettized will outlast unprepared white oak. On the German railroads, the returns of several lines show that Burnettized fir (this being the timber which corresponds to our hemlock) endures in the track from 14 to 15 years. A similar result has been obtained in this country on the Lehigh and Susquehanna Railroad, on the Vermont Central Railroad, and on the Chicago, Rock Island and Pacific Railroad, as well as experimentally on the Erie Railway ; and such failures as have occurred can be directly traced to improper treatment, such as attempts to impregnate wood while yet full of green sap, or the use of too strong a solution, which tends to make the wood brittle.

In order, however, to make sure that the estimates shall be eminently safe, I shall assume a life of but 12 years for Burnettized hemlock in the calculations which follow. I am convinced that better results will be attained if the work is well and skillfully done.

I estimate the cost of Burnettized hemlock ties in the track as follows :

First cost of unprepared ties	28 cents.
Hauling ¼ of output at 16 cents each	4 "
Burnettizing	25 "
*Distributing and putting in track	15 "
Total	72 cents.

* In 1874 Mr. Albert Fink took some pains to ascertain what the cost of replacing ties was, and found it to have been 20.7 cents per tie for labor and 4.7 cents per tie for hauling, a total of 25.4 cents per tie on 877 113 ties, put into the main stem of the Louisville and Nashville R. R., from Jan. 1st, 1855, to June 30th, 1874.

The annual charge, therefore, if they last 12 years, will be 6 cents a year a tie, in lieu of the 11 cents a year a tie which the unprepared white oak ties are estimated to cost ; while the annual charges on chestnut and unprepared hemlock are still greater.

The economy, therefore, of Burnettized hemlock ties over unprepared white oak amounts to 5 cents a tie in first cost (77–72c.) and to 5 cents a year a tie upon the number in the track, so that if we suppose two roads of the present mileage of the "Erie"—*i.e.*, with 1 467 miles of main tracks and 517 miles of sidings, on which there are approximately some 5 000 000 of ties, the one laid with Burnettized hemlock would save over the other, if laid with unprepared white oak, $250 000 every twelve years in the first cost, and also $250 000 a year in the average annual charge for renewals of ties.

This economy, however, can only accrue as fast as the road is relaid with Burnettized ties. The works which it is proposed to erect will have a capacity of 300 000 ties a year, but to cover mishaps and detentions it will be safe to assume that only 250 000 ties will be annually prepared. The annual economy, therefore, will be a gradually increasing one, until the whole road is relaid with Burnettized ties. The first year the saving will be only the 5 cents difference in first cost, say $12 500 for 250 000 ties; the second year it will be $12 500 on that year's purchase, and $12 500 more on the annual charge for depreciation of the 250 000 ties put in during the previous year. The third year the saving will be $12 500 in first cost, and $25 000 in annual charges on the 500 000 ties Burnettized during the previous two years, and so on.

The following table shows how this annual economy increases :

1st	year, difference in first cost 250 000 ties at 5c.						$12 500
2d	"	first cost	$12 500,	annual	charge	$12 500	25 000
3d	"	"	12 500,	"	"	25 000	37 500
4th	"	"	12 500,	"	"	37 500	50 000
5th	"	"	12 500,	"	"	50 000	62 500
6th	"	"	12 500,	"	"	62 500	75 000
7th	"	"	12 500,	"	"	75 000	87 500
8th	"	"	12 500,	"	"	87 500	100 000
9th	"	"	12 500,	"	"	100 000	112 500
10th	"	"	12 500,	"	"	112 500	125 000
11th	"	"	12 500,	"	"	125 000	137 500
12th	"	"	12 500,	"	"	137 500	150 000
13th	"	"	12 500,	"	"	150 000	162 500
14th	"	"	12 500,	"	"	162 500	175 000
15th	"	"	12 500,	"	"	175 000	187 500
16th	"	"	12 500,	"	"	187 500	200 000
17th	"	"	12 500,	"	"	200 000	212 500
18th	"	"	12 500,	"	"	212 500	225 000
19th	"	"	12 500,	"	"	225 500	237 500
20th	"	"	12 500,	"	"	237 500	250 000

After the twentieth year, when all the ties on the road have been replaced with Burnettized hemlock (and I may here remark that nearly as good results can be obtained with Burnettized beech), the full annual economy of $250 000 a year will obtain as compared with the present practice.

Nothing has here been said about interest on the sums saved, nor about the certainty that the price of the more durable timbers will rapidly advance in the near future. Such calculations are more or less fallacious, because the cost of interest varies, and because the cheaper woods also advance in price, but I am very clear that it will be good economy to avail of the heavy body of hemlock and beech recently opened up by the extension of the Bradford Branch, by relaying a portion of the road with ties of those woods, Burnettized, before the timber is cut up for other uses. Respectfully,

O. CHANUTE,

Chief Engineer.

APPENDIX No. 18.

ECONOMY OF CREOSOTED TIES.

NEW YORK, April 26th, 1882.

OCTAVE CHANUTE, Esq.,

Chairman of Committee on Wood Preservation, Am. Soc. C. E.

DEAR SIR,—I inclose a calculation to show true economy in the use of preserved railway ties. This economy is not shown in the first cost, but in their longer life and in the relative annual cost per mile of track of preserved and unpreserved ties. I assume sixteen years as the probable service of creosoted soft wood ties, and eight years for unpreserved white oak ties. The former is the average life of creosoted Baltic fir sleepers on the railways in England, where the traffic is almost constant (see Bogart's paper, Trans. Am. Soc. C. E., Vol. VIII, page 18); the latter is all which is claimed for the best oak ties in this country, and they are generally dozy and unsafe during the last two years of their service.

As it is sometimes claimed that the sum representing the extra cost of preserving, if put at interest, would yield enough to replace unpreserved ties when rotten, I make the calculations at compound interest.

Example.—Relative cost per mile of track of white oak ties @ 80 cents each, and creosoted soft wood ties @ 90 cents* each, the quotations at the present time.

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* As the price of creosote at the time of this publication is lower than in 1882, the price at which ties could be creosoted is less in proportion.

April 1st, 1882.	Cost of 2 600 creosoted soft wood ties, @ 90 cents each, for one mile of track...........................	....	$2 340.00
"	Compound interest at 6 per cent. for eight years.....................	....	1 380.60
			$3 720.60
"	Cost of 2 600 best quality white oak ties, @ 80 cents.................	$2 080.00	
	Compound interest for eight years...	1 233.44	3 313.44
April 1st, 1890.	Cost of 2 600 creosoted soft wood ties at the end of eight years' service, already in place, and good for eight years more.....................	....	$407.16
"	Cost of 2 600 new white oak ties to replace those laid in 1882, @ 80 cents each	$2 080.00	
"	Cost of transportation and relaying, @ 15 cents each....................	390.00	
		$2 470.00	
"	Compound interest for eight years, @ 6 per cent. on $2 470.00..........	1 464.71	
"	Compound interest on cost of 2 600 creosoted ties, good for eight years, $407.16..........................	....	241.44
April 1st, 1898.	Balance in favor of soft wood ties per mile of track during service of sixteen years......................	....	3 286.11
		$3 934.71	$3 934.71

Further, the annual cost for ties per mile of track laid with best white oak ties, @ 80 cents each, during a period of sixteen years, is..		$453.01
Ditto, of creosoted soft wood ties, @ 90 cents each, is.....	$241.31	
Balance in favor of creosoted soft wood ties per annum, during a period of sixteen years, is....................	211.70	
	$453.01	$453.01

That the life of creosoted soft wood ties in this country will probably be sixteen years seems evident from the experience on the Central New Jersey Railroad, which has had laid in its main line, and under very heavy traffic, 10 000 creosoted Virginia pine ties during the past six years, and, so far, they show no signs of cutting under the rail, and are perfectly sound and apparently good for ten years more service.

From the above figures it appears that the cost of the creosoted ties for the ninth year is $407.16 per mile, or about equal to the annual cost of white oak ties during the first term of eight years, *i. e.*, $414.18. Hence, if under the heavy rolling stock at present in use the creosoted soft wood ties will not last sixteen years, they will effect a saving of $414.18 per mile of track for each and every year of service beyond nine years.

A service of sixteen years is allowed for trunk roads with very heavy traffic, but on roads with smaller business and with less wear on the ties, if absorbent woods be used, so that the treatment of the ties can be thoroughly done, it is safe to claim for creosoted ties a service of twenty-four years. (The English ties belonging to the Society are perfectly sound after twenty and twenty-two years wear, even on the London and Northeastern and the Southwestern Railways, where they were subjected to the whole immense traffic of those roads.) On a lower estimate for white oak ties, say 60 cents each, and an assumed life for creosoted soft wood ties of twenty-four years and costing 90 cents each, the annual cost of white oak ties lasting eight years, requiring two renewals, with an additional charge of 15 cents per tie for expense of transportation and relaying at each renewal would be...................... $227.50
While that of creosoted soft wood ties would be only.......... 97.50

An annual saving per mile of track of.................. $130.00

I realize that the above figures and considerations will not be applicable in every case, but I hope they may serve to induce engineers to give a careful consideration to one of the most effective means of reducing the expenses of railway road-beds.

Yours truly,

Edward R. Andrews,
Assoc. Am. Soc. C. E.

APPENDIX No. 19.

Economy of Preserving Timber.

By B. M. Harrod, M. Am. Soc. C. E.

The discussion of the methods and results of preserving timber leads, to the question of relative economy, and when they can be profitably used. To make this clear, a statement has been prepared with regard to two of the most important uses of timber, viz., cross-ties and bridges, showing what increase of life or duration, under processes of different cost, is necessary to justify their use, by economic considerations. The prices and duration assumed are intended to be a fair average of those prevailing throughout the country. The method of computation can, of course, be applied to figures altered to suit different localities and circumstances.

If unpreserved ties cost 40 cents to deliver, and 15 cents to lay, spike and tamp, 2 600 can be laid to the mile at a cost of $1 430. Assuming five years as the average life of such ties, 520 of them must be renewed annually.

Each one will cost, in place, say 65 cents, or 10 cents more for relaying than for the first laying, amounting to $338, annually, per mile. This sum, capitalized at 6 per cent., is $5 633.33. Now, the original cost of ties, plus a capital whose interest will maintain them, can be fairly considered a fixed sum, from which the relative economy and required life of preserved ties can be deduced. This, as estimated above ($1 430 + $5 633.33), is $7 063.33 per mile.

Now, assuming that a tie costing 40 cents can be carried to and from the preserving works for 5 cents, and preserved for 20 cents, and laid for 15 cents (total 80 cents), we have $2 080 as the first cost of 2 600 ties in a mile. This, deducted from the fixed sum, leaves $4 983.33, capitalized, for maintenance, producing $299 per annum at 6 per cent. With a renewed tie costing 40 cents, preservation 20 cents, extra transportation 5 cents, and relaying 25 cents (total 90 cents), the interest on the balance for maintenance ($299) is only sufficient for 332.22 new ties per mile, or 1 in each 7.83, annually. It is therefore necessary, in order to justify a cost of preservation of 20 cents per tie (or of 25 cents, transportation included), that the average life of each should be 7.83 instead of 5 years, or an increase of two years and ten months.

In like manner we find that a cost of preservation of 40 cents per tie must insure an average life of 10.68 years; a cost of 60 cents a life of 14.29 years; a cost of 80 cents a life of 18.99 years, and a cost of $1 a life of 25.37 years. Also, that an indestructible tie is worth, in place, $2.72.

These results can be checked in a table, as follows:

First Cost.	Interest.		Annual Renewals.		6 per cent. on $7 063.33.
($1 430 at 6 per cent.	= $85 80)	+ ($\frac{2\ 600}{5}$	= 520.00 at	.65 = $338.00)	= $423.80
(2 080 " "	= 124.80)	+ ($\frac{2\ 600}{7.83}$	= 332.22 "	.90 = 298.80)	= 423.80
(2 600 " "	= 156.00)	+ ($\frac{2\ 600}{10.68}$	= 243.45 "	$1.10 = 267.80)	= 423.80
(3 120 " "	= 187.20)	+ ($\frac{2\ 600}{14.29}$	= 182.00 "	1.30 = 236.60)	= 423.80
(3 640 " "	= 218.40)	+ ($\frac{2\ 600}{18.99}$	= 136.93 "	1.50 = 205.40)	= 423.80
(4 160 " "	= 249.60)	+ ($\frac{2\ 600}{25.37}$	= 102.47 "	1.70 = 174.20)	= 423.80

If we assume the cost of bridge timber at $15 per thousand, its framing at $15, and its average life at seven years, we find, by applying a similar computation to 100 000 feet, that a cost of preservation of $5 per thousand requires a life of 8.8 years; a cost of $10 a life of 10.85 years; a cost of $15 a life of 13.3 years; a cost of $20 a life of 16.2 years, and finally, a cost of $25 a life of 19.7 years to justify its use.

The rigid application of such a statement as this would be modified by certain general considerations which are sufficiently obvious.

The more inferior the material, or the more exposed the situation, the greater is the relative importance of preservative processes. Five years additional life doubles the value of material which, unprepared, would only last five years, while it only adds 50 per cent. to the value of material naturally good for ten years. Under this consideration, the inferior pines, gums, and even cottonwood, might be used for ties.

Again, difficulty of access for inspection or repair is a good reason for preservation, even when its immediate economy is not apparent. This would apply to piles and bedded or concealed sleepers.

Also, the use of more enduring materials reduces the cost of maintenance of engineering constructions in various indirect ways that are difficult of estimate in a general statement. For instance, if cross-ties lasted twelve years, instead of five, five men could do the work of replacing over a length of road that now requires twelve men.

Under the present rate of consumption, such scarcity of raw material as will very greatly enhance its value is in the near future. There is a wise economy in limiting the use of our wood-land wealth to the rate at which it accumulates, as well as in preventing other well-attested evils that will surely follow the deforesting of the national domain.

It is therefore reasonable to claim that when the economy of preserved and of unpreserved lumber, based on relative cost and durability, appears evenly balanced, there are still reasons, perhaps remote, but certainly valid, why a preference should be given the former.

APPENDIX No. 20.

Formulæ for Computing Comparative Economy of Railroad Ties.

By the late Ashbel Welch, Past President Am. Soc. C. E.

In finding the comparative economy of railroad ties of different prices and durabilities, we may either suppose that they will, on giving out, be replaced by the same kind in the future indefinitely, or we may confine our comparison to the ties used at the present time.

In the former case we find the present value of the sum of the advantages of an indefinite succession of one kind over another, in the latter case we find the present value of the advantage that a single tie of one kind has over another. The amount of advantage will therefore be greater in the former case than in the latter.

Let W be the cost, and let it also be assumed to be the true value of a white oak tie that will last in the track where it is to be placed the time T, including in the cost transportation, handling, use of storage room, interest between the time of payment and use, putting into the track and all other expenses.

And let a be the rate of accumulated compound interest for the time T.

Let c be the cost of some other kind of tie that will last in the same track the time T', including all expenses as above, and also any cost of treatment for preserving it, and any excess in handling, use of storage room and interest while being treated ; and let a' be the rate of accumulated compound interest for the time T'.

Let us first suppose that whatever tie is adopted is to be replaced in perpetual succession by the same kind of tie, and that costs and durations remain constant.

Let L be the loss on renewal of the white oak tie, and L' of the other kind being the total cost of the tie laid in the track, including the same kind of charges as above, and taking out the old tie and putting in the new, the loss on spikes and injury to rails while making the change, and all interruptions and risks, and deducting the value, if any, of the old tie.

Also let V be the value of a tie that in the same track, all things remaining constant, would last forever, and let R be the real value for that track of the other kind of tie as compared with the unpreserved white oak tie.

Then the differences between c and R will be the advantage or disadvantage of the other kind of tie in comparison with the white oak.

The current charge against the white oak tie after renewal at the end of the term T is $a\,W + L$. Against an indestructible tie it would be $a\ V$. But in order that one shall be just as advantageous as the other, their current costs must be equal, so that $a\ V = a\ W + L$, and dividing by a we have $V = W + \frac{L}{a}$.

In the same way we have $a' V = a' R + L'$ and $V = R + \frac{L'}{a'}$ and $R = V - \frac{L'}{a'}$ in order to make R, or what would be the cost of the other kind of tie, just as advantageous as the white oak.

Let $W = 0.80$, $T = 7$, $L = 0.80$, $c = 0.65$.
$T' = 5$ and $L' = 0.65$.
If interest is 7 per cent., $a = 0.62$ and $a' = 0.41$.

Then $V = 0.80 + \frac{0.80}{0.62} = 2.09$ and $R = V - \frac{L'}{a'} = 2.09 - \frac{0.65}{0.41} = 0.505$.

So that for perpetuation in that track, traffic and prices being constant, the tie (chestnut) that costs 65 cents is only worth 50½ cents.

Suppose $c = 0.45$, $T' = 3.5$, $L' = 0.45$, and $a' = 0.272$, the interest for 3½ years.

Then $R = V - \frac{L'}{a'} = 2.09 - \frac{0.45}{0.272} = 0.436$,

or within less than a cent and a half of the cost of the hemlock tie, *i. e.*, 45 cents.

If we compare the ties for their own lifetimes the differences will not be so great.

The economic depreciation of the white oak tie (which may differ widely from the physical depreciation) at the end of the time T' when its competitor gives out is $a' V - a' W$. This is equal in the case of the chestnut tie to $(0.41 \times 2.09) - (0.41 \times 0.80) = 0.53$ the present value of which is $\frac{0.53}{1 + 0.41} = 0.376$. Add to this the present value of accumulated interest for that time $= \frac{0.80 \times 0.41}{1.41} = 0.23$, and we have the true value of the chestnut tie $= 0.609$, or a little over four cents less than it costs.

The economic depreciation of the white oak tie in the lifetime of the hemlock tie, 3½ years, is $(0.272 \times 2.09) - (0.272 \times 0.80) = 0.35$; to which add accumulated interest for 3½ years, or say: $(0.80 \times 0.272) = 0.2176$, which makes 0.5676, the present value of which is $\frac{0.5676}{1 + 0.272} = 0.446$, this being the relative value of the hemlock tie, which is less than half a cent less than its cost.

If the white oak can be made to last 14 years by some treatment, it would be worth for perpetuation, supposing its renewal costs its present time value $R = V - \frac{R}{1.62}$; (1.62 being the accumulated interest for 14 years). Hence $2.62\, R = 1.62 \times 2.09$ and $R = 1.29$. So that it would pay to spend 49 cents on the white oak tie in order to double its lifetime.

The economic depreciation of one white oak tie or any other whose cost was its true value, for the lifetime of any other tie T' is $a' V - a' W$.

The accumulated interest on the cost of W up to the same time is $a' W$.

To get the present value of each of these we divide by $1 + a'$, the sum of the quotients being the real value of a tie that will last the time T'. But we may as well add the depreciation and interest together and divide the sum by $1 + a'$.

Thus $\frac{V a' - a' W + a' W}{1 + a'}$ is the result we want, but we see on inspection that this equation is equal to $\frac{V a'}{1 + a'}$ and get a simpler equation. Assuming the longer lived tie to cost its true value, then the true value of the shorter lived tie is $= \frac{a' V}{1 + a'}$.

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THE PRESERVATION OF FORESTS.

By F. COLLINGWOOD, M. Am. Soc. C. E.

READ AT THE ANNUAL CONVENTION, JUNE 25TH, 1885.

(Being Appendix No. 1, presented with the Report of the Committee on the Preservation of Timber.)

At the Washington meeting of the Society, the writer had the task assigned him of preparing an appendix to the report on Preservation of Timber, in which should be presented, in brief form, such facts as are obtainable respecting the necessity for exercising economy in the use of forest products, because of the very rapid extinction of forests over considerable areas of our country, and the apparent possibility of what might be called a wood famine.*

Important as the subject is, the information to be had is on many points exceedingly vague and unsatisfactory, and of so general a character as to afford but little basis for exact estimates.

* This matter was prepared in the spring of 1884, before the ninth volume of the U. S. Census was in print. The writer would refer to the latter for additional information on the subjects treated, although it is not such as to change materially the conclusions drawn. The writer holds very positive views as to the value of forests in ameliorating local climatic conditions, but was requested by the chairman to be as brief as possible, and he therefore confines himself rigidly to the economic side of the question.

In connection with the last census, arrangements were made under the intelligent leadership of Prof. C. S. Sargent, of Harvard, for a series of exhaustive reports, which were to cover the whole area of the United States. The final report has not yet been published, and there are many gaps not filled by the bulletins thus far issued. Other sources of information consulted have been the series of valuable papers presented at the Montreal meeting of the American Forestry Congress, maps, cyclopædias and newspaper articles. The statistics are quite full in regard to the available supply and annual cut of white pine, and the several species of Southern pine suitable for timber; less complete as to cedar, spruce, tamarack and hemlock, and very incomplete as to black walnut, ash, oak and other hard and soft woods.

To form any intelligent conclusions it is necessary to consider the subject in detail.

Taking white pine (*pinus strobus*) first, as being at present the most important commercially, we learn that its original area of distribution was, in Canada, from about the 50th degree of north latitude south to the boundary, east to the Gulf of Newfoundland, and west to about Lake Winnipeg. In the United States it occupied portions of Minnesota, Wisconsin, most of Michigan, Pennsylvania, New York and the Eastern States, and extended south in the Allegheny Mountains to Northern Georgia.

The supply and the amount cut in the census year ending May 31st, 1880, are given in the following table:

State.	Amount now Standing.	Cut in Census Year.	Years of Supply at same rate.
	Feet, B. M.	Feet, B. M.	
Minnesota...........	8 170 000 000	540 997 000	11 years.
Lower Michigan......	29 000 000 000	4 085 213 000	7 "
Upper "	6 000 000 000	328 438 000	19 "
Wisconsin...........	41 000 000 000	2 097 299 000	20 "
Pennsylvania........	1 800 000 000	380 000 000	5 "
Maine...............	475 000 000	138 825 000	3 "
New Hampshire......	Original pine all cut.	2d growth. 99 409 000	
Vermont............	" " "	2d growth. 6 505 000	
West Virginia........	990 000 000	180 112 000	5 "
Totals....... ..	87 435 000 000	Omitting 2d growth. 7 750 884 000	11 "

We thus arrive at the astonishing result that in so far as the supply of first growth white pine is concerned, it will be practically exhausted in 11 years. The amounts standing in New York and other States, not mentioned above, are not large enough to change this result, and the cut in the three States first named has greatly increased in the three years succeeding 1880. Even if the supply be double what it is estimated, the necessity is already upon us of conserving to the uttermost these most valuable of our forest trees. "The lumber cut in a single year from the district of Michigan, Wisconsin and Minnesota would load a train of cars nearly 7 000 miles in length, and a single mill in Michigan made 160 000 000 shingles in the same time."

It is well known that from this district, with Canada, our lumber yards now draw the most of their supplies. It is only necessary to visit the southern shore of Lake Superior, Minneapolis and other lumber centers in the vicinity, and see the exceedingly rapid increase of the trade year by year, to become convinced that the estimate given as to time of extinction of white pine in the United States cannot be far wrong.

As to the Canadian supply, Mr. Ward, an intelligent, practical lumberman, places the annual cut of pine lumber at 2 000 000 000 ft., b. m. Of this nine-tenths is exported. The area annually cut over is about 4 700 square miles.

Prof. Hough, of Ontario, says all the timber (meaning, I presume, pine) will be cut in Canada by the end of the present century.

It is stated that lumber is now being cut from points 200 to 300 miles north of the St. Lawrence, or nearly to the extreme northern limits of the pine.

The statistics of the red pine are not given, although in the North it is next in commercial importance to the white pine.

Passing to the various Southern pines, the species of value are principally two: the long-leaved or yellow pine (*pinus palustris*), forming extensive forests in North and South Carolina, Florida and the Gulf States; and the short-leaved or spruce pine (*pinus mitis*), occurring in all the Atlantic States south of New York, in Arkansas and in the Gulf States. Statistics are given as follows:

	Long-leaved Pine Supply.	Cut in the Census Year.	Short-leaved Pine Supply.	Cut in the Census Year	Years will last, both kinds together.
	Ft., B. M.	Ft., B. M.	Ft., B. M.	Ft., B. M.	Years.
Texas	20 508 200 000	66 450 000	26 093 000 000	146 420 000	219
Florida	6 615 000 000	208 054 000	....	....	32
Alabama	18 885 000 000	245 396 000	2 307 000 000	....	87
Mississippi	17 200 000 000	108 000 000	6 775 000 000	7 775 000	145
North Carolina	5 229 000 000	108 411 000	....	....	48
Louisiana	26 588 000 000	61 882 000	21 625 000 000	22 709 000	570
			(Estimated from Bulletin map.)		
Georgia	16 778 000 000	272 473 000	2 500 000 000	28 335 000	64
Arkansas	....	....	41 315 000 000	129 781 000	319
			(Estimated from Bulletin map.)		
South Carolina	5 316 000 000	124 492 000	1 000 000 000	....	50
Timber omitted as having been damaged by abstraction of turpentine	By estimation. (?)10 000 000 000	....	....	....	....
Total	127 119 200 000	1,195 158 000	101 615 200 000	335 020 000	150

The other States furnishing more or less of these pines are Tennessee and Virginia ; but it is very safe to say that if included in the statement they would actually reduce the average. From the time that white pine began to be scarce in the oldest settled States the use of Southern pine has been steadily increasing. Yellow pine, spruce and hemlock are coming more and more into use, and to the exclusion of white pine for many purposes. The long-leaved pine furnishes the tar, resin and turpentine of commerce ; and trees tapped for this purpose are estimated to lose 20 per cent. of their value for timber.

A third species, the loblolly, or spruce pine (*pinus taeda*), is found from Virginia to Florida, and west to southeastern Texas. It grows up quickly also on lands which have been exhausted by cultivation. The timber is, however, of inferior quality, and subject to rapid decay. In Texas alone the supply is estimated at 21 000 000 000 ft., b. m., and the cut at 61 570 000 ft. in the census year.

In the extreme West, the Rocky Mountains and the Sierras, are several other species of pine, of large size, and valuable for timber, but no statistics are given. Among these are the *pinus ponderosa*, growing to 300 ft. high and 15 ft. diameter ; the *pinus jeffreyi*, reaching 200 ft.

high and 10 ft. diameter; the sugar pine, largest specimens 300 ft. high, 20 ft. diameter, and 600 years old, "timber very valuable and the tree fast becoming exterminated;" and several smaller species.

O the red-wood of California there is an estimated supply of 25 825 000 000 ft., and the cut in the census year was 186 635 000 ft. The use of it is rapidly increasing.

Of spruce definite returns are given as follows:

	Supply Remaining. Ft., B. M.	Cut in Census Year. Ft., B. M.	Years of Supply. Years.
Maine	5 000 000 000	301 020 000	17
New Hampshire	1 510 000 000	153 175 000	10
Vermont	755 000 000	199 086 000	4

The New York market has drawn its supplies from these States, but it is manifest that a source more remote must soon be sought. The spruce in some of its species extends north far beyond the pine, reaching to the Arctic Ocean, near the mouth of the Mackenzie River. Its range otherwise is about the same as the white pine, and it is found in the Alleghenies as far south as North Carolina. Other species valuable for timber are found in the extreme West, extending from California and New Mexico through Oregon, Washington, Alaska, and probably to the Arctic Ocean. The timber from the spruces, firs, larches and cedars will be immense in quantity and of great value.*

The next statistics refer principally to the common hemlock. The range of this is "from New Brunswick and Northern New England westward, crossing the St. Lawrence near Quebec," and extending around the great lakes to the western end of Lake Superior.

Its southern limits are much the same as spruce, it being found in the mountains of North Carolina.

There are several valuable species of hemlock in the extreme West, growing to large size, and having a wide range of distribution.

The statistics given are of the common hemlock, and are very meager.

	Supply, ft., B. M.	Cut in Census Year.	Supply will Last. Years.
Lower Michigan	7 000 000 000	....	..
Pennsylvania	4 500 000 000	300 000 000	15

* In Upper Michigan alone the estimate of the supply of tamarack, white and yellow cedar is 62 500 000 cords, or 95 000 000 000 ft., b. m.

The only estimates of hard wood given are the following :

	Supply in ft., B.M.	Cut in Census Year.*	Supply will Last at this Rate. Years.
Minnesota	88 473 000 000	40 800 000	2 170
Lower Michigan	883 968 000 000	520 307 000	1 700
Upper Michigan	191 232 000 000	1 145 000	....
Wisconsin	....	155 872 000	....

In Oregon, Washington, California and Alaska there are great areas of timber of all kinds, considerable portions of which are estimated as containing 50 000 feet, board measure, to the acre, and over. Fifteen cords of hard wood, or 23 000 feet, board measure, per acre, is a good yield in the East, and one writer estimates the average yield of pine from Canada pine lands at only 2 000 feet per acre. An estimate of the average yield of white pine from two counties in Pennsylvania gave 4 000 feet per acre.

The total amount of lumber cut in the United States for the census year is given at 18 091 000 000 feet, b. m. In addition were 1 762 000 000 laths, 5 555 000 000 shingles, 1 248 000 000 staves, etc. The total consumption of wood for fuel, including about 1 000 000 cords for charcoal, is estimated at 145 778 137 cords.† This would consume all the hard wood in the State of Michigan in about five years.

A writer in the *Railway Review* says: On extra good wood lands there are 270 ties to the acre, but the average is scarcely 160.

There are now, he says, on the railroads in the United States, 335 000 000 ties, requiring 3 272 square miles to be cut over every six years to supply them, or an area equal to about two-thirds that of Connecticut.

Another writer makes the area one-third of this for heavily timbered land.

Still another estimate (by one of the Committee on Preservation of Timber) is, that there are now 200 000 miles of track in the United States, with 2 500 ties per mile, or 500 000 000 ties in use. Prof. Hough states, in a report on the "Durability of Cross Tie Timbers," that it requires 17 000 000 acres, or 26 500 square miles of forest, to furnish the present demand of the railroads in the United States for ties. This is evidently on the supposition that about 40 years are required for trees to grow to the required size.

It is estimated that a strip of land 200 feet wide along each mile of road, heavily planted with trees, would furnish this supply.

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* This is inclusive of amounts cut for staves and headings. In the case of Upper Michigan it is stated that it does not include fuel and railroad ties, and presumably this is true for the other States.

† This reduced to feet, b. m., gives 224 000 000 000 feet in round numbers, or about 12 times the amount of wood cut into lumber.

Other drains on our forests arise from farm fencing, telegraph and other electrical lines, tunneling, mining operations, piling and other engineering operations, ship building, etc.

As to notes respecting scarcity, we find remarks as follows:

Dr. Chas. Mohr, of Mobile, says: "The white oak is becoming scarce in densely settled districts. The invasion and partial destruction of large sections of forest on the lands of the government near the railroad lines through the mountains of North Alabama has been very extensive, and the supplies are getting rapidly exhausted by the constantly increasing demand."

Of the chestnut in the same region he says: "Trees of the finest proportions are ruthlessly cut down for their fruit, and the demand for its timber for fencing has also led to its extinction near the settlements. The trees would be rapidly reproduced from the quick-growing sprouts if they were not destroyed by the forest fires."

Of black walnut he says: "In Alabama it is getting scarce; fine tracts are at present destroyed (burned, I suppose he means) in districts remote from transportation."

The live oak "has almost ceased to exist as a timber resource."

The basket oak, taking the place in the South, for carriage building, &c., of our white oak, "is rapidly passing away."

The waste spoken of here is not confined to Alabama. Vast quantities of hemlock in the North have been destroyed for nothing but the bark, and in newly settled regions great quantities of wood of various kinds are burned for the purpose of clearing the land.

All these sources of waste are, however, as nothing compared with the losses from forest fires. Mr. G. L. Marler, of Montreal, says: "The Province of Quebec is being rapidly denuded of timber. Years ago the elms were burned for the manufacture of potash from the ashes. Then the pine was cut off, and afterward the less valuable woods; 'but forest fires are worse than all else.'"

Mr. Joly says: "The greatest enemy to fight is forest fires." Mr. Thistle, of Ottawa, estimates that in that region "ten times as much timber is burned as is cut." In the upper lake region the forest fires are frequently so extensive in the fall as to cover the whole country and the lakes with a dense pall of smoke for weeks. All must remember the terrible fires on the shores of Lake Michigan of recent occurrence; and in the month of April, 1884, very extensive fires ranged over a strip of country several hundred miles long in the States of North and South Carolina, nearly destroying the turpentine business over a large area in these States.*

* The total estimated loss by fires in forests in the United States during the census year is $25 462 250, but many towns and counties where fires occurred made no reports, and the loss is probably much larger than this. Of 267 fires reported in Michigan, 161 were traced to fires set in clearing land for agricultural purposes, 59 to hunters, 43 to sparks from locomotives, 3 to smokers and 1 to the Indians.

Wind storms and insects are also agents of destruction, whose ravages are not to be overlooked.

Before attempting a summary of the statistics given, it is only fair to state that other writers point to the magnificent forests yet almost untouched in Virginia, Tennessee, North Carolina, eastern Kentucky and southern Ohio, and the supplies from the southern and extreme western States; then when these are exhausted, Canada, the Valley of the Amazon, etc.; also the great areas of second growth timber in all the older States. Another important fact, and one which tends to conceal the growing scarcity in the older districts, is the paramount use of coal for fuel, almost to the exclusion of the use of wood, over considerable areas. The areas given on the map of the Forestry Bulletin show about 10 per cent. of the area settled as coal burning, 25 per cent. as burning coal and wood, and 65 per cent. as wood burning. A remark made by Prof. Hough, of Washington, is very suggestive. He says: "As the supplies of a once timbered region begin to fail, the deficiency is made up from more distant points; and so long as there are regions within reach of railways where the materials can be found for supplying the trade, we shall not realize the extent of the exhaustion until we nearly approach the end."

With this extract, let us leave the opinions of others and ask ourselves what conclusions we can reach as to the duration of timber supplies. In the light of the statistics given, we find:

1st. The supply of white pine in the United States is certain to be exhausted before the end of this century, and good judges predict the same result for the Canadian supply.

The price in the last twenty-five years has about trebled at tide-water, and there is no wood to take its place except at greatly increased cost for transportation.

2d. Of Southern pines, at the present rate of consumption, there is stated to be 150 years' supply. Even if this be greatly underestimated, the geometrical increase in the population of the country and the corresponding increase in consumption of timber, together with the immense and inevitable losses by fire, seem certain to reduce this limit.

3d. The supply of spruce in the United States, east of the Mississippi, is not fully given; but there would seem to be not over 25 years' supply. There are, however, large supplies of this and other soft woods to be drawn from in Canada and the West.

4th. Of hemlock, the supply in the East is about the same as that of spruce. It will soon be exhausted in Pennsylvania, New York and the Eastern States. The price has about doubled in 25 years, and an advance in price sufficient to warrant transportation will bring large supplies from distant points.

5th. Of hard woods, black walnut began to be used extensively less than 25 years ago, and the price has advanced to $110 per M., at whole-

sale. The supply is being rapidly exhausted. Ash has more than doubled in price, and oak, also, in the same time.

The supply of large timber in all these is destined to rapid extinction in the older settled districts. The supplies to be drawn upon are so great that we cannot predict a famine, except in some of the species. We *can* say that prices will continue to advance, as timber is brought from greater distances, and the cost of transportation is increased.

The subjoined letter, kindly written by Prof. Sargent on request, gives an interesting resume of the whole matter:

ARNOLD ARBORETUM, HARVARD UNIVERSITY,
DIRECTOR'S OFFICE,
BROOKLINE, MASS., March 30th, 1884.

My Dear Sir,—I am very sorry that I am unable to give you the information you desire.

The only estimates of standing timber made by the Census Office have been published in the various Forestry Bulletins. It was impossible to cover the various hard woods in the same manner. The only danger of a short supply in the country is confined to the white pine, spruce, possibly hemlock, and a few hard woods, such as black walnut, white ash, hickory and cherry. Of other hard woods there is still an abundant supply. Good timber is not, however, so generally distributed as formerly, and many of the older States are about stripped of all sorts, or nearly so. Great hard wood forests are now only found along the slopes of the Allegheny Mountains; in Arkansas, Louisiana, and other Southern States. A large part of these forests is inaccessible by rail, and as the oak and other heavy timbers are too heavy for "driving" down the streams, they are still saved from destruction.

The exhaustion, however, of the timber supply in more accessible regions will soon bring even the most remote of the hard wood forests into market. It will be necessary, in considering the supply of hard woods, to take into consideration the increased cost of transport from remote localities to the centers of consumption.

Yours very truly, C. S. SARGENT.

MR. F. COLLINGWOOD,
Elizabeth.

So far as we are concerned, therefore, as engineers, the matter becomes one simply of cost; and in this view alone it is evidently worth our while to economize in the use of timber.

As a matter of ethics, however, something more is due from us. It is our bounden duty to try in every way to prevent the terrible losses of timber by fire. Our locomotives are responsible for an immense amount of this mischief, and the fact is discreditable to the profession.

In cutting and burning the way for new lines through wooded countries, also, forest fires are frequently started.

In pursuit of our duty we come in contact with the backwoodsman, and we can spread sound knowledge as to the sure profit eventually to result from the preservation of the forests, and particularly of the large timber, and inculcate greater care in brush burning and the use of fire in other ways in the woods.

It is pertinent here to make a quotation from the census report respecting the supply in Wisconsin: "The annual growth of timber (in this State) is counterbalanced by the annual waste by windfalls and natural decay of old trees. The loss by fire is probably 5 per cent. of the whole. The lumbermen waste the upper part of the tree, which is not knotty but sound. From an ordinary sized tree four 16-foot logs are taken and the top log left. This is often 22 inches in diameter at the butt, and would scale from 100 to 120 feet. This is done because the pay of the loggers is small, and they cannot afford to cut the fifth log. Nearly one-tenth of the timber is therefore left in the woods and wasted.

We can also point out the profit that may be expected in many parts of the country from the cultivation of certain kinds of wood, particularly on ground which would otherwise be waste. In connection with this branch of the subject, the following notes of growth are given by various writers. These will, of course, vary with variations in conditions; and it should be remembered that the larger the tree, and the more dense and valuable its timber, the slower the growth becomes.

A sugar maple will grow to 15 inches diameter in 30 years; a white larch to about three feet in diameter in 50 years; a butternut to 12 inches diameter in 24 years; a willow to 18 inches diameter in 27 years; a black walnut to 24 inches diameter, under favorable circumstances, in 50 years, but it will not have the handsome grain of larger and older trees; a live oak grows to 30 inches diameter in 70 years; a basket oak to 42 inches diameter in 180 years; a white oak to 39 inches diameter in 200 years, and a white pine to 2 feet to 3 feet diameter in 37 years. It can be satisfactorily shown that when tree culture is intelligently undertaken in regions where timber is scarce, a fair return is made on the investment, and it begins within a few years from the first planting.

As engineers, we are called upon to study the subjects of water supply, and the effects of floods upon structures, and in causing changes in streams, etc. Now, however much opinions may vary as to the effect forests may cause by inducing local climatic changes, there can be no question as to their efficiency as conservators of the water supply of the region where they are, and of their tendency to equalize the flow of streams and prevent floods.

The public at large certainly need education upon this very important subject.

In closing this report the writer regrets that the information cannot be made more exact, but trusts that it may enable our members to form

a reasonably correct idea as to the future of the supply of timber in our country, that material upon which the success of so many of our enterprises depends.

The great unknown factor is *waste*, and we in common with all good citizens are interested in the introduction of some thorough system by which this great wrong shall be done away with. If *this* be done, and reasonable care be taken to replant forests where circumstances warrant the expectation that it can be done with profit, we may safely rely on an abundance of timber for generations to come.

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DISCUSSIONS

ON THE REPORT OF THE COMMITTEE ON THE PRESERVATION OF TIMBER; AND ON THE PRESERVATION OF FORESTS.

AT THE ANNUAL CONVENTION OF THE SOCIETY, JUNE 24TH, 1885.

JAMES B. FRANCIS, Past President Am. Soc. C. E.—Perhaps my experience in the matter may be of some interest. I commenced Kyanizing in 1848, for some corporations I was connected with, and some of the work I then did is now in existence. It was said that Kyanizing in England was a failure, and in 1848 I made a journey to England to find what the reasons were. One reason was that the parties in England who were carrying it on were cheating in conducting the process. Another was that the Bethell process had just then been introduced, and the leading engineers were taking it up, and the result was that only two or three parties were using Kyanizing, but there seemed to be no sufficient reason for it. I saw Faraday and Brunel and others interested in it and they could give me no good reason why it had gone out of use. On my return Burnettizing was coming into favor. There were some advantages claimed for it, as economy and facility in carrying it on. Strong recommendations were made that it was equally good. Competent chemists that I consulted thought there was no doubt that it was just as good; so I dropped Kyanizing and went to Burnettizing, and it took ten years to find out my mistake. Kyanizing, done before Burnettizing, was stand-

ing where Burnettizing had failed ; so we went back to Kyanizing, and that has continued up to the present day. The purpose we have used it for in Lowell is for the numerous bridges on the canals, which were decaying rapidly, and the result is that the cost of maintaining these bridges is reduced to about one-half by Kyanizing. Not that it is a perfect preservative, by any means, but it has increased the durability of the wood to a great extent. I put up, in 1850, a fence of spruce around a reservoir, which is still perfect. That was about 35 years ago, and it is a perfectly good fence now ; not a single piece has been renewed ; it has partly decayed under ground, but all above ground is perfectly good. I think the cottonwood might be made available for many purposes by this process. I have some cottonwood preserved in that way. I do not say it is perfectly sound, but it is in good condition ; whereas the unprepared cottonwood is nothing but black mold. There can be no doubt about the preservative effects in lengthening the life of wood either by Kyanizing or by Burnettizing. We have found the Kyanizing answer our purpose the best, and we have followed it ever since. My experience has been long enough to leave no doubt whatever about it ; it extends from 1848 to this time. Creosoting, I have no doubt, is a still more perfect preservative, but the expense and difficulty of doing it prohibit its use here to a great extent. Kyanizing is only a preventive of rapid decay ; that is all that is claimed for it ; it delays the decay.

E. A. Fuertes, M. Am. Soc. C. E.—I have had some little experience in regard to Burnettizing that has led me to believe that the process is not always effective. In 1869 or 1870, the City of New York was largely under the control of Tweed, and many contracts were given out for the paving of streets with wood, and one of the contracts called for Burnettizing the blocks. Very soon after the contract was given and this pavement was laid, Mr. Tweed fell, or rather was pushed out ; and there was appointed a commission to investigate his frauds. I was appointed engineer of that commission and took up the pavement. Part of it I took to Prof. Chandler to analyze the wood and see what he found. Apparently nothing had been done ; no chloride of zinc had been injected into the wood. But the other side, the contractors, introduced Dr. Wurtz to testify, and he swore that not only was the wood Burnettized, but that he himself had done it. The pavement had been laid down for a year or a little over. We then had some of the blocks which had not been laid down examined and found they had been fully Bur-

nettized, and after that we took up some of those which had been laid down, and in a cart load of those, there was just a trace found of the chloride of zinc. The inference from the facts was that in the course of a year the chloride of zinc had washed out of the wood.

D. J. Whittemore, Past President Am. Soc. C. E.—Some 15 or 18 years ago we unfortunately had a wooden bridge of 247 feet span burned down on a line of road I am connected with, and we were very anxious to have the bridge we should build in its place protected from decay. We therefore had the lower part Burnettized, and took upon us to see that the process then in operation was perfectly carried out. Twelve years afterward, and about six years ago, the bridge parted its lower chord, consisting of six pieces, and that was the very part that we had Burnettized. We were quite anxious to determine whether anything remained of the chemicals that were injected. We had pieces from various parts of that chord taken out and gave them to Mr. Shaler Smith, who had them analyzed, and he reported that not the least trace of the preservative chemicals was to be found in the wood.

Prof. E. A. Fuertes.—Dr. Wurtz used a three and a half per cent. solution, but the fibers of the wood were vertical, and that evidently helped considerably to the washing out of the solution.

T. Egleston, M. Am. Soc. C. E.—I have been somewhat surprised in listening to this very able report to hear nothing whatever in regard to the age of the wood which it was attempted to preserve, nor in regard to the time of its cutting. So far as my examination of wood, as a metallurgist, is concerned, I find it absolutely necessary to pay the very greatest possible attention not only to the age of the wood but to the time it is cut. It has been found by a series of experiments lasting some 35 or 40 years that if wood is cut during the month of January, then ranked up, and afterward used, its life may extend without any preservative whatever, in wood of proper character and age, for 15 or 16 years, whereas wood of the same species, if cut at a different age and time, may last only three or four years.

At the Cleveland Convention of this body I gave a succinct account of these experiments made by the German Government. These woods were made into wine barrels, etc., and buried in the earth for the purpose of ascertaining how far they could be used for different purposes.

I think that a part of the failures in these preserving processes can be ascribed entirely to the circumstance of the wood being cut in the

wrong season of the year. Other failures may be attributed, I think, to the fact that the wood is of improper age. It is the habit of a great many persons cutting timber to cut it at any season of the year, and I have not infrequently, in many parts of this country, been able to establish the fact that for metallurgical purposes not more than ten per cent. of the value of the carbon contained in the wood was made use of by the company that was using it. I am quite sure that if the time of cutting was taken into consideration some of these processes would be found of very great value. There are some of them, however, based upon false principles; chemically they are impossible; they could not be carried out in a laboratory on a small scale, much less on a large scale. If these processes were investigated on a large scale, as they should be, we should not have our Government paying thousands of dollars for processes entirely useless.

J. J. R. Croes, M. Am. Soc. C. E.—The inspection of the method of preparation of any timber, while the work is in progress, which is impressed so strongly by the Committee in this report, seems to me very necessary. I let a contract during this past winter for the impregnation of railroad ties with not less than ten pounds of dead oil to the cubic foot. I required the contractor to notify me when and where the process was to be applied. I received notice one day that two days later the timber would be creosoted in North Carolina. I insisted upon delay in the matter, and sent an inspector immediately to the creosoting works, who found that this timber which was to be impregnated with ten pounds of dead oil was, at the mills where it was cut, first put for two or three hours into a cylinder and heated, and then put into an open tank of oil which they said was dead oil, and there lay for three hours, being turned over with a pike pole, and was then shipped on board a schooner. This dead oil was cold when they put the timber in and cold when they took it out after three hours. They said there was ten pounds of oil in. I sawed one of the sticks in two and found it discolored about an eighth of an inch from the surface. Of course, I did not take the timber, and I found it could not be properly impregnated at that place or by that process, especially as the oil used was not dead oil, but was chiefly a product of the distillation of pine wood. They claimed that it was better than creosote. I found that the only place the work could be done conveniently was in New York. The timber, North Carolina pine, was shipped to New York and was impregnated with dead oil at creosoting works in Brooklyn. The

requirement in most of the authorities is that there should be not less than ten pounds of oil to the cubic foot, but I found on further examination that it depended very much on the size of the stick how much oil was necessary for its preservation, that it took thirty pounds of oil to the foot to impregnate timber throughout, and that it took from forty-eight to sixty hours in the charging chambers to impregnate ordinary timber to that extent. After the timber has been put into the cylinder and steamed, and all the moisture driven out in that way, and then the oil put in under pressure, ten pounds of oil will go in in the course of five or six hours into timber 8 by 8 or 6 by 6; but to put in twelve pounds of oil takes several hours more, to put in fourteen pounds takes still longer, while to put in sixteen or twenty pounds takes several hours longer, which increases the cost very much, the cost being dependent in a very great measure on the length of time the operation takes. I found on cutting these sticks that when there was ten pounds of oil it penetrated about a foot into the ends of the sticks, and it went in about half an inch into a stick 8 by 8; that is, the timber, when it was sawed in the middle, showed the presence of the oil about half an inch deep. For railroad ties which were to be put on iron girders and notched from half to three-quarters of an inch, according to the adjustment of the grade, on an iron trestle, it did not seem to be safe to take ten or twelve pounds, because in the harder portions of the stick the oil went in barely a half inch, in some cases not quite so much. So I had fourteen pounds of oil put into the timber, in which case it went into the softer parts one and a half or two inches, while in the harder parts it went in a little over half an inch as a general thing. I have preserved sections of the sticks which were impregnated with different quantities of oil, all cut from the same stick of timber. Pieces about 5 feet long were put into the machine, and then sections about two inches thick were taken from the middle of these pieces, which showed just how the oil penetrates the wood and how necessary it is to make the quantity of oil dependent upon the area of the sticks, or rather on the periphery of the stick. The oil goes into the end of a stick some distance, but to preserve the stick, especially if it is to be cut, it must enter into the wood on the side for a certain distance, according to the use the timber is to be put to. It is evident that a stick of twelve or sixteen inches square will not need as much oil as a six-inch stick. The smaller the stick, to get the requisite amount of penetration of the oil—that is, to have the wood preserved to a requisite distance

from the outside in—the greater the proportion of oil to the cubic foot which is necessary. Therefore I don't think there is any absolute rule to be applied in regard to the amount of oil to be used for impregnating. It ought to be made dependent upon the depth of the stick to which you want the oil to penetrate, and then by actual experiment in each case find what amount of oil it takes to penetrate that distance. For a pile 12 or 14 inches in diameter, to thoroughly protect it from the teredo, it was stated by the operator that it was necessary to thoroughly saturate it, which takes about thirty pounds of oil to the cubic foot of North Carolina pine.

J. F. Flagg, M. Am. Soc. C. E.—Do I understand that with a larger stick you need more oil?

Mr. J. J. R. Croes.—No, the larger the stick the less oil to the cubic foot is required to impregnate the periphery to a given depth.

Charles Latimer, M. Am. Soc. C. E.—I have listened to this report with a great deal of interest, and I think it the clearest and most valuable paper I have heard on this subject. It has gone into the matter very thoroughly, and the Committee deserve the thanks of the Society and the public. There are some facts probably that it would be well for me to state, inasmuch as my experience gives me the right to mention them, and it would be well that they should go on record. In relation to the life of timber, I have had a very fair opportunity of judging what the life of ties should be in eleven years of experience on one road in which I had the entire charge of purchases of all kinds. We have 800 miles of road. That will give us 2 000 000 of ties. In the time mentioned we bought something over 2 200 000, so that every tie, or nearly every tie, had decayed in that length of time. The life of ties of oak, which are the most of our ties, is eight years; in bridges, nine years. Now, that statement in relation to the value of ties is quite important. Eleven years ago we paid 50 cents for ties; to-day we are paying 45 cents per tie. Although the contractor says each year it is impossible to get the ties, he manages that we can get without difficulty just as many as we want, and now, not, I suppose, that I would be unable to get them from along the line, I am going to Michigan, where I can get cedar ties delivered for 40 cents. I want to state facts which may be of value to correct any statement or misapprehension in relation to timber. The facts are important in that regard. In relation to the wear of timber, I know of timber which I saw taken up. I know where it was brought from positively, as

I have the witness of very responsible parties; it was planted in palisades, stockades. It is seventy years old and perfectly sound. I refer to the catalpa tree. I planted some of those trees, but they gave me the wrong seed, and now in five years I have got a lot of scrub trees which ought now to be ties, but they are only three or four feet high. Coming to the question of preparing ties, I have had a little experience. I bought 20 000 Thilmany process ties. I bought them delivered at Mansfield for fifty cents per tie ; the process of preparing them cost 15 and 20 cents a tie. I thought I had a very good bargain, and I congratulated myself upon getting a set of ties that would last me a very long time ; but I am sorry to say that the report of the Committee is entirely borne out in the later examinations of those ties, as we find they are mere shells. Therefore, my experience with ties preserved by the Thilmany process is entirely unsatisfactory. I have no other experience in the preserving of ties; but the facts that I have given bear upon the question, and it seems to me are important.

Mr. James B. Francis.—There is one matter alluded to in this report which I did not speak of, and that is the poisonous nature of Kyanizing. We never found the slightest trouble with it in that way. Since 1848, with an interval of perhaps ten years, there has been no case where the men operating in it have been made ill. Once in a while the men working over the tank where the material was dissolved in hot water have complained somewhat of it, but I never knew any man made seriously ill. The men go into the tank with bare feet, and it seems to be rather healing to cutaneous diseases. The only danger seems to me to be from the efflorescence on the surface of the wood. The timber sometimes becomes white on the outside from the salt in it, and that might be licked off by cattle. The white substance on the timber is corrosive sublimate. That is very poisonous, but as to the process we have had no trouble whatever.

Mr. J. J. R. Croes.—I would like to ask from the Chairman of the Committee what there is to be said about a process that I do not see mentioned in the report, the process of wood vulcanizing, as it is called, or subjecting the wood to heat in some way, and converting the sap into rosin and hardening the wood so that it is claimed that it will last forever when used for railroad ties or for any other purpose.

Mr. Charles Latimer.— Iwant to say that if any process can be obtained which will double or add 50 per cent. to the life of ties, using the

cedar or the hemlock, of course there is an immense economy in it, and I trust that some one has that process, for it would pay us to use it. I can get cedar ties from the northwest at 35 cents, and hemlock ties at 30 cents on the road, so if ties were to be preserved and cost no more than 50 cents, and would last 15 years and hold a spike well and not become brittle, it would certainly be very valuable.

Prof. T. Egleston.—So far as my experience goes in making investigations on woods, any process whatever which causes any chemical change to take place in the substance of the wood makes the wood brittle. The moment there comes to be any change in the color of the wood from heat, the wood becomes entirely unfit for constructive purposes. Almost all these processes have in view the production of acetic acids. If the process is carried so far as to give an acetic acid, the wood is not good for anything. If the process is not carried so far as to get good acetic acid, the acetic acid commands a very small price, and the wood is not good for anything but kindling.

A. W. Locke, M. Am. Soc. C. E.—One point I do not hear alluded to in the report of the Committee, and that is the cost of removing old ties from tracks or bridges and replacing them with new, which would have a very favorable effect upon the figures given by the Committee. I have observed that the cost of replacing ordinary ties after they are delivered on the ground is about 10 cents per tie year by year. That would have to be taken into account, and would probably be 25 per cent. of the amount of saving effected. Then in replacing ties upon bridges it will cost one or two dollars per lineal foot of bridge to place ties upon bridges where traffic is being carried on.

Mr. Edward P. North.—Some wooden pavement was laid on Fifth avenue, between Thirty-second and Thirty-third streets, about a year ago. The wood was brought from England already "creosoted." There was very little creosote in the wood, and I brought some to the Society room that smelled more decidedly of the pine than of the creosote on the outside of it. Horace Loomis, M. Am. Soc. C. E., Assistant Engineer to the Department of Public Works, has a specimen in his office that is noticeably free from creosote, I think that must have been creosoted as Mr. Croes' North Carolina pine was. When that wood pavement fails it will probably be cited as a proof of the uselessness of creosoting. A surveyor in London, who was laying a wood pavement on Brompton Road, told me that creosoting was of no use, that the "dipping"

was not worth anything; and as many English engineering publications speak of the necessity of having wood dry before creosoting, it is possible that dipping in hot oil is resorted to instead of the more thorough methods generally in use in this country. At any rate, in case of creosoting or any other process proving a failure, the method employed should be investigated and given with the record of a failure.

Prof. E. A. Fuertes.—Prof. Egleston mentioned something in reference to the amount of carbon depending upon the age of the wood. I would like to know if he has made any experiments as to the amount of carbonates in the wood, or rather as to what functions they have in the wood.

Prof. T. Egleston.—I cannot remember the figures, but where the wood is cut after the sap rises it is so porous that it will not bear any weight, and so when I said that not more than ten per cent. of the carbon was contained in the wood, I did not mean that the carbon had undergone any change, but the material was so porous that it would not stand the weight of the charge in the furnace, and had to be thrown away.

Mr. Charles Latimer.—Mr. Crowell is here, and he has been over to Europe and saw some steel ties there. The question is if we may use the steel with economy. He has seen steel ties in use there, and he knows their cost. The question is whether we can afford to use the Burnettized and creosoted ties in comparison with the steel ties.

Prof. T. Egleston.—In 1869 Mr. Krupp told me that he never should use another wooden tie. In the year 1882, and last summer, I made a special trip to Europe with reference to testing this question of steel ties and their manufacture. It is known now in Germany that it is cheaper for them to lay down steel ties made by the Bessemer process than to use wooden ones. The large works there are turning out now basic Bessemer steel ties whose life has been determined to be so long, whose extra stability in a permanent way has been found to be so great, that they are being sold all over Germany. In the North Western Steel Works, in the North of England, they are already making these steel ties, and I think in time the steel ties will very largely supersede the wood ties. I will ask Mr. Crowell to state his experience.

J. F. Crowell, M. Am. Soc. C. E.—I will not occupy the time of the Convention at any length. What I saw of the metal ties would not be of special interest here, I think, but it convinced me of the entire practica-

bility and adaptiveness of the most improved tie used in those German roads that I examined. In regard to the cost, the late Mr. Lorenz, of the Reading Railroad, procured several specimens of the ties, and made an estimate with the object of introducing them on the roads he was then connected with, and he found, if I remember correctly, that the price would be in the neighborhood of $7 000 per mile; that is, for the ties only, for say 3 000 ties per mile, which would be a large cost compared with the first cost of the wood ties. The wearing of the steel ties might be three or four times as great as that of the wooden ties, and that added to the saving of replacing the wooden ties would probably reduce the cost at the end of the life of the steel ties to something less than the cost of the wooden ties. The cost he figured was the duty added to the cost of the steel tie which he could then buy in Germany. If steel ties could be brought down somewhere near the price of steel rails, the tie weighing one hundred and ten pounds would perhaps cost $1 50 in round figures, as against the average cost of the wooden tie. The initial cost, however, is not a fair test of the value of a permanent steel tie. If we can get a tie that will not deteriorate, and which can be relied upon to stay in the track without so much work, the economy of a high-priced tie would, perhaps, be very great. In Germany they have experimented with a number of different forms. The particular form that I saw in use was the latest. It was simply a channel extending with its flanges into the ballast and with a very simple fastening. Bolts were used in the fastening to connect the rail with the tie, and that is a form we would probably find objectionable. They do not seem to find it so there, but we have a good deal of trouble with four bolts to the rail, and with fifteen or sixteen more the matter of the bolts would be a serious question. But if we can get a simple tie of that form with a secure fastening, which will not require too much attention to keep in good condition, I think the economy in substitution, even at the present time, would justify its use in many cases.

F. Collingwood, M. Am. Soc. C. E.—By request of the Chairman of the Committee I took up the subject of the question of cost, and have written very briefly upon it.

The report gives in the appendices three different methods of estimating the economy to be derived by using some process for preserving ties. That by Mr. Andrews gives the money saving at the end of the term of life of the preserved tie. That by Mr. Harrod, the life that the preserved tie must have in order to make the cost of using preserved or

unpreserved ties equal. That by Mr. Welch, the money value of any tie in use when compared with the white oak unpreserved tie taken as a standard; the difference between this money value and the cost showing the economy or loss in use.

In the first and last of these investigations the authors have compounded the interest on the several costs; in the second case simple interest only has been taken. This is a point that must be settled before any close agreement can be reached in the discussion. While theoretically it is correct to use compound interest in all computations of this kind, practically the results are often misleading. Wherever the interest remains in hand, and is reinvested as principal, as in the case of Savings Institutions, or Life Insurance Companies, the interest can be compounded, but even then all expenses for management or losses of any kind must be deducted annually; so that in very few cases is full compound interest ever realized, that is, interest compounded at the full legal rate.

Now, railroads are not lenders but borrowers. Their accounts show each year a large amount paid on interest account, and, as a prominent item in working expenses, renewals of ties. Compound interest never figures there, and even if there be a renewal fund on interest, the interest is spent each year and cannot be compounded. "You cannot eat your cake and have it too."

In making comparisons it is necessary, also for fairness, to compute interest on all sums paid out to the end of the term of life of the longest lived tie; otherwise interest will be charged at the end of the shorter life on the interest which has accumulated on the difference in first cost. This tells against the longest lived tie, and makes Mr. Andrews' method not quite fair to himself.

By his suppositions and methods (using simple interest), the saving per mile by creosoting is $3 086.10, but by taking interest on the one side on $2 340 for 16 years, and on the other on $2 080 for 16 years, and $2 470 for 8 years, the actual saving is shown to be $3 146, or 151 per cent. on the cost of first laying of the cheapest tie.

Table No. 1 following gives a few results worked out by this method. By this it seems that the rate of interest paid makes no material difference in the percentage of economy obtained by preservation of ties. As the cost of ties increases, the economy increases rapidly. As the cost of preservation increases the economy diminishes rapidly.

On the supposition that an unpreserved tie before laying cost 40 cents, first laying 15 cents, and renewals 15 cents more (or a total of 55 cents in new track, and 70 cents when in old track), and that it will last 5 years; also that a preserved tie will cost 25 cents more and last 12 years, with interest at 6 per cent.; this table (see No. 7), shows a saving per mile every 12 years of $2 400, or 169 per cent. on the cheaper tie. If the life of the preserved tie be 16 years, according to European experience, the saving per mile will be $4 700 (see No. 5).

If a preserved soft wood tie with life of 12 years cost 75 cents in new track, and an unpreserved oak tie will last 8 years and cost 80 cents, then the saving per mile will be $2 050 (see No. 11), or about the same as the cost of the oak ties.

As there are now in round numbers 500 000 000 ties in use in railroads in the United States, if these were all of oak, the saving by substituting preserved soft wood ties under the last conditions would be about $410 000 000, or $34 000 000 per year.

If a preserved oak tie costs in new track $1.05 and lasts 16 years, and the same unpreserved costs 80 cents and lasts 8 years, the saving per mile will be about $2 400 (see No. 14), or on all the railroads in the United States about $30 000 000 per year.

These figures are given to illustrate in a familiar way the very great importance of the subject as an economical question. The share capital of all the railroads in the United States in 1884 was, according to Poor's Manual, $3 708 060 583, and the net profits $336 911 884. Hence, if such a saving can be made, it will pay nearly 1 per cent. per annum on the share capital, and about 10 per cent. on the net profits.

Table No. 2 is computed by Mr. Harrod's method; a column of results, according to his method, is also added to Table No. 1. It will be found by comparison that its results are not quite as favorable to the preserved ties, the differences being due to slight variations in the interest account.

The difference between the figures in the last column of Table No. 2 and the actual life of the preserved tie in each case shows the measure of economy by its use. The first method is the most direct of all.

Mr. Welch takes the unpreserved oak tie as a standard, and determines the value of any other tie by taking account of its first cost and the interest accumulating during its life. The difference between the value by formulæ of the tie under examination and its first cost

gives the gain or loss by its use. When used with simple interest, the formulæ give anomalous results, as will be seen by the last two columns in Table No. 3.

The incompatibility of results by these formulæ, when compound interest is used, is shown by reference to that part of the appendix where a comparison is made between ties "for their own lifetime." Taking the first case there mentioned, the various results can be put in the form of an equation, which will be seen to be identical, thus :

$$\frac{0.41 \times 2.09 - 0.41 \times 0.80}{1 + 0.41} + \frac{0.80 \times 0.41}{1 + 0.41} = \frac{0.41 \times 2.09}{1 + 0.41} = \frac{a' v}{1 + a'}$$

In other words, the result arrived at for the true value of the cheaper tie is nothing more than the present worth of the interest which would accumulate during the first term T', on the value of the indestructible tie. In the case of the hemlock tie, this becomes :

$$\frac{2.09 \times 0.272}{1 + 0.272} = 0.447$$

If, however, we make the comparison for the second half of the life of the oak tie, we have to take account of the interest which has accumulated during the first half, and the oak tie must be charged with a capital of $v + \$0.568$. We get for the second term, therefore, a present worth of :

$$\frac{0.272\,(2.09 + 0.568)}{1 + 0.272} = 0.568$$

or the hemlock tie worth 12 cents more than cost $(0.57 - 0.45 = 0.12)$.

It is manifest that C W and R will each be increased by the same amount when considered as applying to renewal ties, as in the case of relaying an old track, and the results by the formulæ will not be changed.

TABLE No. 1.

Computed by the first method indicated above, counting 2 600 ties per mile, with a column added for comparison with results by Harrod's method.

Number.	Kind of Tie.	Rate of Interest.	Life of Ties.	Cost of each Tie in New Track.	Cost per Mile of New Track.	Cost per Mile of Renewals (at 15 cts. each additional).	Cost of Preserved Ties at end of Life.	Cost of Unpreserved Ties for same length of time.	Saving per mile by use of Preserved Ties.	Per Cent. of Saving on Cost of first laying of Unpreserved Tie.	Time that highest-priced Tie must last to be of equal value with the other, as given by Harrod's Formula.
			Years.								
1..	Preserved soft..	6 per cent.	16	90 cts.	$2 340		$4 586 40				
	Oak...........		8	80	2 080	$2 470		$7 732 40	$3 146 00	151	$9\frac{31}{100}$ years.
2..	Same	5 "	16	90	2 340		4 212 00				
			8	80	2 080	"		7 202 00	2 990 00	144	$9^{\underline{23}}$ "
3..	Preserved soft..	6 "	16	80	2 080		4 076 80				
	Soft...........		8	55	1 430	1 820		5 496 40	1 419 60	99	$13^{\underline{12}}$ "
4..	Same	5 "	16	80	2 080		3 744 00				
			8	55	1 430	"		5 122 00	1 378 00	91	$12^{\underline{67}}$ "
5..	"	6 "	16	80	2 080		4 076 80				
			5	55	1 430	"		8 772 40	4 695 60	328	$7\frac{62}{100}$ "
6..	"	5 "	16	80	2 080		3 744 00				
			5	55	1 430	"		8 216 00	4 472 00	313	$7^{\underline{45}}$ "
7..	"	6 "	12	80	2 080		3 577 60				
			5	55	1 430	"		5 990 40	2 412 80	169	$7^{\underline{62}}$ "
8..	"	5 "	12	80	2 080		3 328 00				
			5	55	1 430	"		5 655 00	2 327 00	163	$7^{\underline{45}}$ "
9..	"	6 "	12	75	1 950		3 354 00				
			7	50	1 300	1 690		3 950 14	596 14	46	$11^{\underline{52}}$ "
10..	"	6 "	12	75	1 950		3 354 00				
			5	50	1 300	"		5 514 60	2 160 60	166	$7^{\underline{83}}$ "
11..	Preserved soft..	6 "	12	75	1 950		3 354 00				
	Oak...........		8	80	2 080	2 470		5 405 40	2 051 40	99	$7^{\underline{39}}$ "
12..	Same	6 "	12	75	1 950		3 354 00				
			7	80	2 080	2 470		6 062 88	2 708 88	130	$6^{\underline{49}}$ "
13..	"	7 "	12	75	1 950		3 588 00				
			7	80	2 080	"		6 455 98	2 867 98	138	$6^{\underline{45}}$ "
14..	Preserved oak..	6 "	16	$1 05	2 730		5 350 80				
	Oak...........		8	80	2 080	2 470		7 732 40	2 381 60	114½	$11^{\underline{57}}$ "
15..	Same	7 "	16	1 54	4 004		7 927 92		129 22	6 per ct. in favor	
			8	80	2 080	"		7 798 70		of unpreserved.	$25^{\underline{25}}$ "
16..	Preserved soft..	6 "	12	90	2 340		4 024 80				
	Soft...........		5	65	1 690	2 080		6 942 00	2 917 20	173	$7\frac{59}{100}$ "

TABLE NO. 2.

Computed by Harrod's Method with a Constant Price for Unpreserved Ties, and an Increasing Price for Preserved Ties.

No.	Kind of Tie.	Rate of Interest.	Cost of each tie in New Track.	Cost per Mile of New Track.	Cost per Mile of Renewals (at 15 cts. in addition).	Life of Cheapest Tie.	Yearly expenses.	Investment required to produce this amount.	Last Item + First Cost of Cheap Ties = "fixed sum."	"Fixed sum" Less First Cost of Preserved Ties.	Annual Interest on this Balance.	Number of Preserved Ties this will lay in renewal each year.	Time Preserved Ties must last to make both kinds of equal value.
18..	Preserved	6 per cent.	.80	$2 080	$2 470							At 95 cts. ea.	
	Unpreserved		.55	1 430	1 820	5 years.	$364	$6 066 67	$7 496 67	$5 416 67	$325 00	342 11	7.60 yrs.
19..	Same	"	1.00	2 600	2 990							At $1 15 ea.	
			.55	1 430	1 820	"	"	"	"	4 896 67	293 80	255 50	10.18 "
20..	"	"	1.20	3 120	3 510							At $1 35	
			.55	1 430	1 820	"	"	"	"	4 376 67	262 60	194 52	13.88 "
21..	"	"	1.40	3 640	4 030							At $1 55	
			.55	1 430	1 820	"	"	"	"	3 856 67	231 40	149 30	17.42 "
22..	"	5 per cent.	.80	2 080	2 470							At 95 cts.	
			.55	1 430	1 820	"	"	7 280 00	8 710 00	6 630 00	331 50	348 95	7.45 "
23..	"	"	1.00	2 600	2 990							At $1 15	
			.55	1 430	1 820	"	"	"	"	6 110 00	305 50	265 65	9.79 "
24..	"	"	1.20	3 120	3 510							At $1 35	
			.55	1 430	1 820	"	"	"	"	5 590 00	279 50	207 04	12.56 "
25..	"	"	1.40	3 640	4 030							At $1 55	
			.55	1 430	1 820	"	"	"	"	5 070 00	253 50	163 55	15.90 "

An indestructible tie on basis of No. 25 is worth $3.35 = $8 710 / 2 600

At 7 per cent. " " " 25 " 2.55

" " " 18 " 2.88

TABLE NO. 3.

COMPUTED FROM MR. WELCH'S FORMULA (AT SIMPLE INTEREST).

No.	Rate of Interest.	T	T'	a	a'	W	L	V	L'	R	C	Loss on each cheaper Tie.	Loss by First Method (for comparison).
26..	7 per cent.	7 yrs.	5 yrs.	.49	.35	\$0 80	\$0 80	\$2.433	\$0 65	\$0 57½	\$0 65	7½ cts.	\$331 50 or $9\frac{1}{10}$ cts. ea. for each cheap tie used.
27..	6 "	7 "	5 "	.42	.30	"	"	2 70½	"	53½	65	11½ cts.	325 00 or $8\frac{9}{10}$ " " "
28..	6 "	8 "	5 "	.48	.30	"	"	2 47	65	30	65	35 cts.	741 00 or 18 " " "
29..	7 "	7 "	3½ "	.49	.24½	"	"	2 43	45	60	45	Gain ea. 15 cts.	100 45 or 2 " " "
30..	6 "	7 "	3½ "	.42	.21	"	"	2 70½	"	56½	45	Gain ea. 11½ cts.	123 50 or 2½ " " "
31..	6 "	12 "	5 "	.72	.30	"	95	2 12	70	21	55	Loss ea. 76 cts.	2 412 80 or 39 " " "
32..	6 "	16 "	8 "	.96	.48	1 05	1 20	2 30	95	32	80	Loss ea. 68 cts.	2 381 60 or 46 " " "

DISCUSSION
ON THE PRESERVATION OF FORESTS.

C. J. H. Woodbury, M. Am. Soc. C. E.—In the State of New Hampshire, with a view to encouraging the growth of trees along the public highways, they have a law which gives a modification of taxes to those putting up drinking troughs for live stock or planting trees along the highways. Wherever that has been done it was in the most perfunctory way, merely enough to cover the law.*

A few years ago my attention was called to the catalpa as a tree furnishing a source of lumber which resisted decay. I procured some seeds of the *catalpa speciosa* from Dayton, Ohio, and planted them in Northeastern Massachusetts in 1879. Those trees have now reached the height of nine feet. I had 100 of them, but when they were about four feet high an over-vigilant gardener weeded out most of them, but the remainder are growing well and are in a flourishing condition, and I hope to see them to the size that the tree grows in the Middle States. Some were planted on alluvial soil; some on high, rocky and naturally sterile ground. That is, as far as I have been able to learn, the most northern growth of the catalpa tree. If I may be permitted to allude to the interesting report of the Committee on Preservation of Timber, presented last night, as far as the report of that committee has gone, the use of lime upon timber subjected to the direct dampness of the earth, water, or what is worse, alternate wet and dry, was not successful, and yet the experience of every one of us shows that under other conditions lime is a preventive of decay, especially against dry rot, as long as the wood is not subjected to conditions which remove the lime. Who ever knew a lath to decay? As an instance of the efficiency of lime in the preservation of wood against decay, I may cite the case of a mill in Claremont, N. H., where the basement was blasted out of a very seamy ledge, through the fissures of which there came a great deal of water, either by springs or infiltration from the canal. It was blasted out to the depth of two feet below the floor, and the stone chips replaced to within four or five inches to the grade of the floor. As it came nearer to the top of the stone filling, finer and finer stone was selected, and upon that lime, gravel and air-slaked lime, and then the spruce was laid directly upon the lime. That was in 1856. Last spring I was at the mill when

* See note at the end of this discussion.

repairs were being made, and found that the under side of those planks was penetrated by dry rot to the distance of an eighth of an inch, showing that the use of lime had served to protect the floor against dry rot for twenty-nine years, under exceptionally difficult circumstances. The use of wire lathing has been carried on for many years, chiefly as a protection against fire. The earliest use of it was in Paris in some of the buildings erected under the administration of Bonaparte as First Consul, which I have been informed are still in sound condition. At the Boston Theater, in a place where dry rot might be expected, around large spaces in the decoration, where such lathing was put on in 1853, an inspection of the timber work, back of the lathing, last year, showed it to be in a thoroughly sound condition. It seems to me that the effect of dampness is rather more deleterious to wood than running water, for I have seen wheel pits of mills where the ends of the timber against wet ledges would be sound, while further up, where it was subjected to dampness rather than to the direct application of water, signs of very rapid decay were shown. In the matter of the preservation of timber, a great deal of it decays because it surrounds a confined air space. I have known the basement floors of mills within four feet of the ground to show signs of sweating in a very few days when the air was confined, but when the air space was open and a circulation of air forced under the mill, the timber dried and the dry rot was stopped entirely. The ventilation of timber is a very important phase of its preservation, and much of the decay of timber would have been prevented, if due care had been exercised in the protection of ends exposed to the weather, and the ventilation of confined spaces.

Note.—Since the meeting I have had a search made among the statutes of the States, and learn that the legislation on this subject seems to be directed into three classes; nineteen States have protective laws, which, by the enactment of severe penalties upon those who injure trees, defend the owner to an extent wholly beyond the remedy furnished by the common law; the second class, comprising seventeen States, have subsidizing laws, which still further encourage tree cultivation by direct bounties and abatement of taxes, in addition to defenses against trespassers; the third class are without legislation on the subject, and include the seven States of Florida, Kansas, Louisiana, Maryland, North Carolina, Texas and Washington.

Kansas had a law containing provisions for giving bounty to persons for planting trees (General Statutes 1868, chap. 112), which was repealed (Laws of 1874, chap. 76).

Texas has a law which gives a railroad corporation permission to cut timber where it chooses.

Of the States with protective laws which purpose to defend trees already grown rather than to encourage the planting of trees, Alabama (Code 1876, §§ 4425–4428; Statutes 1879, No. 137; 1885, No. 64) is chiefly devoted to the protection of the pine forests in the turpentine interest; also prescribing penalties against destroying ornamental trees and setting fire to forests.

In Arizona the provisions (Code 1877, p. 96) refer to injury to shade trees. In Arkansas (Digest 1884, §§ 1658–1660; also §§ 1956–1959) the laws prescribe penalties for cutting timber, and setting fire to forests. Connecticut (General Statutes 1875, title 19, chap. 17, § 7) has penalties for cutting and destroying trees. Dakota (Code 1883, §§ 704, 708) makes the penalties cover malicious injury to timber, fruit or ornamental trees. In Delaware (Revision 1874, p. 777) the law indicates the nursery interests in the State by fixing the penalty for *taking* ornamental or fruit trees. Stealing a tree, and not a portion or product of it, seems a novel theft, and certainly would not occur except around nursery gardens.

The laws forbidding injury to timber and ornamental trees in the following States contain provisions which are, on the whole, quite similar to each other in the desire to protect a person in whatever he chooses to do in the way of tree planting. The references are as follows:

Georgia, Code 1882, §§ 4440, 4615. Indiana, Revised Statutes 1881, §§ 1928, 1961. Minnesota, Statutes at Large 1873, pp. 885, 994, 1003. Mississippi, Code 1880, §§ 961–965. Montana, Ohio, Oregon, Pennsylvania have numerous laws on this subject. South Carolina, General Statutes 1882, §§ 1167, 2501, 2512. Tennessee, Code 1884, §§ 5403, 5425. West Virginia, Revised Statutes 1878, chap. 41, § 28. Virginia and Wyoming complete the list.

The elaborate provisions in the laws encouraging arboriculture are followed by conditions which require that the bounties must be *earned*, and give rise to the presumption that in some instances such laws were drafted by enthusiasts, and amended by practical politicians. The estimate of the value of tree planting to the community is widely different in various States, and the amount of the bounty may be taken as an index of the popularity of such legislation.

California recognizes the value of trees along the highways, by making it obligatory upon the County Supervisors to encourage road-side cultivation and pay to the planter $1 for every living tree 4 years old (see Code of California, §§ 13, 384, 2755 and 4080). Colorado (Code 1883, §§ 3425, 3426) has enacted the peculiar provision that the planting of trees shall not increase the assessed value of land until 10 years after planting ; and that an annual premium of $2 for every 100 trees shall be paid from the fourth to the tenth year after planting.

Idaho, in the Act of January 4, 1875 (Revised Laws, page 712) goes

even further, and exempts from taxation for a term of 10 years tracts of planted trees over 5 acres in extent.

Illinois (Revised Statutes 1880, chap. 136) permits county boards to offer a premium of $10 per acre. Iowa has elaborate provisions, allowing partial remission of taxes on forest plantations (Rev. Code 1880, §§ 798, 3889, 3899, Acts 1880, chap. 190).

The laws of Maine (Revised Statutes 1881, p. 144) show that the immense lumber interests of that State are beginning to feel the effects of indiscriminate felling of native forests, as their present laws exempt from taxation for 20 years land containing 2 000 forest trees planted on each acre. In the great lumber State of Michigan, the bounty is framed for the encouragement of tree planting along the highways (Statutes 1882, § 1408, 1410, 9129, 9171, 9173, 9174, 9193, 9405, 9407).

The Commonwealth of Massachusetts allows towns to raise money to plant shade trees (Public Statutes, chap. 27, § 12), and also encourages growth of ship timber (chap. 114, § 8), and exempts timber plantations from taxation between the fourth and tenth years. Missouri (Revised Statutes 1879, § 5697) fixes the forest bounty at $2 per acre for 15 years. Nebraska gives a bounty of the compromise sum of $3.33 per acre, and limits the application of the payment to plantations of 3 acres. Also compels towns to plant shade trees, and levies special taxes therefor (Compiled Statutes 1881, p. 52).

The laws of Nevada (Compiled Laws 1872, §§ 3838, 3842 ; Statutes 1877, chap. 113) are similar to those of Colorado, in limiting taxation and giving bounties.

In New Hampshire the towns may raise money to set out shade trees, and abate taxes to persons who do so (Gen. Laws 1878, chap. 37, § 9 ; chap. 281, § 3).

His Excellency the Governor of New Jersey is authorized by the Act of February, 1884, to set apart a day in each year for planting forest trees.

New Mexico (Compiled Laws 1884, § 2809) offers exemption from taxes similar to those of other States.

New York abates highway tax to persons planting shade trees along the roads (Revised Statutes, 7th Ed., pp. 1263, 1235, 1257, 2208, 2517, 2527, 2483).

Rhode Island exempts forests plantations of 2 000 trees to the acre on land worth less than $25 per acre, for 15 years after the trees are 4 feet high. There is not much land within the boundaries of this thickly-settled State, and the amount, whose low value renders it eligible to enter into this competition, must be relatively smaller than in any other State. The State of Wisconsin (Statutes 1871, Title VI, chap. 19, §§ 166–168 ; Title XIII, chap. 77, §§ 32–36) contains elaborate provisions framed to encourage tree planting.

Mendes Cohen, M. Am. Soc. C. E. (Chairman of the Convention)—I may say that further discussion of the question of the preservation of timber is quite open. If any remarks are to be made on that subject in connection with the subject of the preservation of forests, the Convention will be glad to hear them.

James B. Francis, Past President Am. Soc. C. E.—In reference to planting timber, the cottonwood we all know is a very rapidly growing timber, but it decays very quickly. According to my experience, it can be preserved from decay as well as any other wood. I have a cottonwood post in the ground twenty-three years, and it is well preserved yet. If timber is to be planted and cottonwood can be made useful for timber by treatment, it would be worthy of extensive cultivation. It is a rapidly growing timber and can be made a good timber for many uses. It would seem to be worthy of cultivation on the prairies. In ten years, I suppose, probably less, it would be large enough for many railroad purposes. As I said before, I am confident that it can be preserved from rapid decay as well as any other wood.

J. F. Flagg, M. Am. Soc. C. E.—What do you think of the comparative strength of cottonwood and white pine?

Mr. James B. Francis.—I suppose it is very inferior to white pine; but then it grows so much more rapidly, say in 10 years instead of 100, and it has strength enough for many purposes.

Mr. F. Collingwood.—Mr. North spoke of the growth of pine taking so long a time. Those who have ever read closely the proceedings of the Forestry Convention of Montreal cannot help having been struck by the fact that it is possible to make a forest begin to pay its way quite soon anywhere within reach of a market by not waiting for the timber to grow to a size for use as timber, but planting quite thickly and gradually thinning out.

The various writers do not recommend that the choicest farm lands shall be devoted to tree planting, but the many waste places, hillsides, etc., to be found on almost any farm; also a strip of land on the north and west to ward off the cutting winter winds. Various experiences are given showing profits realized annually per acre (after paying rent) of $1.25 up to $50 in an extreme case. The first sum was on land valued at $20 per acre. The returns begin to come in after 5 to 8 years.

The governing principle in forest culture seems to be that the foliage shall at all times be dense enough to protect the soil from the drying

effect of the sun and winds. As a result of this, the trees grow mostly upward; the lower limbs die or are cut off before they become large enough to cause bad knots, and the subsequent annual rings are clear and straight. Thinning begins when the wood is large enough for hoop-poles (if the wood be suitable), then hop-poles, small masts, stanchions, mine timbers, fuel, etc., being carried on systematically, with a due regard to the principle first mentioned.

T. Egleston, M. Am. Soc. C. E.—The experience I have had with timber has been mostly with regard to its use as fuel. It has been shown by long experience in the forestries of Europe that it is quite possible for the farmer to get as good a rate of income from certain kinds of land for timber as from cultivating it in crops. While the use of timber as fuel has no particular interest for this Convention, the same general principle is true as regards fuel as is true of timber, and I am certain that any systematic effort to plant land with timber on mountain slopes would yield as large a return as planting it in crops in any part of the United States. It is true that to get the best kind of timber you have to wait a long time; but in planting a large area of ground, as the French and German Governments have been obliged to, the ground has yielded to the Government as good a return for the capital invested as any other. Their plan is to use it for timber, and the plan Mr. Collingwood suggested is the one they use; they plant a very large number of trees and then thin out. In the course of ten or fifteen years the ground begins to yield an income, and from that time yields an income every year, and as it is thinned out the timber gets more valuable. What is needed in this country is the passage of laws relating to trees. This subject was a matter of so great importance for the preservation of animals on the plains that it used to be my habit when I first went there to get the farmers together and talk to them about the cultivation of trees. I have known large forests of cottonwood to grow up within ten years so as to be large trees from fourteen to eighteen inches in diameter, but in those parts of the country it is only used as a protection against winds. The cottonwood is a great grower, and if anything can be done with it, it would be valuable on that account. But hard wood trees can be propagated as well as others, and what is wanted in this matter is not science but legislation.

A. M. Wellington, M. Am. Soc. C. E.—It has occurred to me that,

while these efforts to preserve the timber supply are very commendable, yet from a certain point of view there is no danger whatever of our failing to have as much timber as it is for the public interest that we should use. The present use of timber in the United States is three or four times as great as in any other country for the same purposes, and five or six times as much as it is for the public interest that it should be. I question very much whether it is a public advantage to have timber over cheap. Even in our large cities the use of timber is much more general than in other parts of the world, and it can be shown by figures that the use of timber is actually costing the City of New York more for insurance and in the maintenance of the Fire Department, and in loss and injury to property, than it would cost to require all buildings to be made fireproof from the beginning. For railroad purposes also, for the platforms and buildings along the track, wood is entirely unsuitable. It is contrary to public interest that these should be built entirely of wood. It would cost very little more to erect brick or stone or concrete buildings or something of the kind, and in the end the public would be better served. I have been for some years in a country where wood is inconceivably scarce. It is found only in the furthermost recesses of the mountains, and when once cut it never grows again. Nothing in this country will compare with it. Nevertheless, the community get along very comfortably. Instead of building houses that will last only eight or ten years, or be burned down in six months, the buildings there will be as good one hundred years from now as they are to-day. To be sure, they require no fire for heating purposes. For cooking, they manage to dispense with wood to a very large extent. Sufficient wood is brought on the backs of men or donkeys from a distance of fifteen or twenty miles. In comparing that situation, which prevails in many parts of the world where civilization flourishes well, with the situation in this country, we find that we have an enormous area where timber will grow freely, and that our supply of timber is sufficient, with ordinary preservation and care, to answer all purposes, to give all the timber we really need. If timber gets high in price, people will use brick or stone and be more comfortable as well as more safe.

J. J. R. Croes, M. Am. Soc. C. E.—Will Mr. Wellington kindly name the country where he has been, so that it may go down as a matter of record?

Mr. A. M. Wellington.—I refer to Mexico. The civilization of

Mexico is higher than people imagine, although, of course, not as high as ours, and it is very interesting to see to what an extent it is possible to dispense with timber. For instance, such things as the piazzas about this building would be made, in Mexico, of light, graceful cut stone work, not much heavier than these piazzas are, and the effect is very beautiful. Here we build with wood, and they very largely with stone. We build in that way largely, I think, from habit. We build a handsome cut stone house and put a wooden piazza outside instead of building arches of stone; I think largely from the fact that they are so little used that it is not realized how little additional cost they involve.

Mr. Edward P. North.—I am surprised to hear a Member of this Society expressing such sentiments. The inconvenience in Mexico from the lack of wood is something no man brought up in this country can understand. The impossibility of getting wood for structural purposes has been a continual drawback to the success of Mexico. They have made makeshifts at a great expense by which to build comfortable houses. The element of permanence which Mr. Wellington has spoken of I think is objectionable. As the country is now growing, with new wants and new appliances for satisfying those wants, any house built to day will twenty years from to-day be inadequate. New appliances will be required which render it necessary that the house shall be taken down and a new one built in its place. In the City of New York there are not two per cent. of the houses, except in the poorest parts of the city, that are not altered in twenty or thirty years at a great expense, sometimes greater than if the houses were torn down and built from the foundation. The necessities of our country are growing so that permanence in a house either for residence or business purposes is not desirable.

Prof. T. Egleston.—I do not know about our houses not being permanent. I am the owner of a house built in 1783. It is a wooden house, and I had occasion to cut out some timber from it lately, mostly oak, and I think it is just as sound as when the house was built. That is pretty permanent I think.

Mr. A. M. Wellington.—I do not think that any one can fairly draw the conclusion from what I said that the condition of things in Mexico in regard to the timber supply, or anything approaching to it, would be anything but a great public evil here. What I did say was that the

conditions in this country are such that, do what we will, there will always be an abundant supply for all legitimate necessities, and that a very large part of our use of timber is a public evil; not all by any means, and that the use of timber very often is not even an immediate economy. The most conspicuous example is in large cities, where wooden cornices, floors, walls, interior fittings, etc., create danger from fire, which costs a great deal more in the City of New York than it would cost to build in the first place of approximately more fire-proof material, so that fires would not be so ever present a danger as now.

Mr. F. Collingwood.—I think we may fairly quote in this connection such a country as Great Britain, which is drawing its supplies to-day from Canada, from this country, and from nearly all the world, and they find it necessary to do it. They can not get large timber except by doing so. I think, as engineers, we would find ourselves in great trouble sometimes if we could not get large timber. Some years ago I wanted to get some white oak piles for a bridge, and I had a good deal of trouble to find them. It is a question of economics. It is not that we cannot get the timber, that it is not in the United States, but the price of timber is rapidly increasing, and as the supply is exhausted which we are now drawing on, we shall have to go further for it, and it will cost us a great deal more. I would be very glad to take up the question of the effect of the destruction of our forests upon climate locally and upon the water supply. Every one who has lived upon a stream for 30 or 40 years knows what a change there has been as soon as trees have been cut off from its head waters. It is a necessity almost upon us to cultivate the growth of timber to help to conserve the water supply and make it more uniform.

Chas. Latimer, M. Am. Soc. C. E.—While I believe that it is a very good thing to preserve timber, and take care of the forests, I think with Mr. Wellington that we borrow a good deal of trouble. I remember, when I was in Buenos Ayres, I was very much shocked to find that all the wood that could be bought was peach trees, and I was very much astonished, when I was out there, at a very remarkable discovery—the discovery of oil in this country. Every one was expecting that the whales would give out and there would be no oil, and all of a sudden more oil was found than we could use. You remember Rankin wrote a paper: "What Shall We Do for Coal in England?" and now they have found that they have abundance of coal. In Wyoming Valley,

where they had a good deal of black coal, the question arose finally, "What are we going to do for cheap coal; it is giving out?" Well, in the Pittsburgh region they have opened up immense gas fields. The next question was, "What are we going to do for steel?" and we are making it now as cheaply as iron. And now the question arises, "What are we going to do for hoop-poles?" But iron is used for hoops almost universally. As to the question of building houses, Mr. Wellington spoke of everything but aluminum. We will have aluminum houses after awhile or some other metal, and not be bothered with wood. I think the trouble of cutting the forests is very much like killing the bears or killing the buffaloes. If you give up cutting timber for 50 years the whole country will be overrun with forests, and the question will be how to get rid of them. The question is not yet serious.

Gustav Lindenthal, M. Am. Soc. C. E.—There is an interesting point in the paper about the preservation of ties. I had occasion to talk with an official in Prague, Bohemia, on the question of renewing ties, and he said they found it a saving to use iron ties when oak ties reached the price of one florin. Iron is 25 per cent. cheaper there than it is here. In respect to the preservation of timber, I would like to state a fact. Preserved timber was used for a bridge floor in Pittsburgh, and to my disappointment and surprise I found it rotten in some places after one year, namely, the wooden blocks set on end between the tracks, where horses rarely step, or that portion of the bridge which is used the least. I am not quite satisfied as to the cause. I think that where the tracks are used the fiber is beaten down and compressed, in this manner excluding the water to a certain extent and preserving the wood. On the other hand, where the surface of the blocks is not compressed by travel the action of rain and sprinkling washes out the preservative and the loose grained and spongy wood rots faster than it would if not preserved. In London and other places, where wooden pavements are largely used, they wear off faster than they could rot. The question, where we shall get a supply of timber from in the future, is an important one. I think there is an invention for making artificial timber from straw. Should the price of timber get so high that we would be obliged to get a substitute for it somewhere, the inventors of this country may find a substance that can be manufactured cheaply. Where nature works slowly they may work fast.

O. Chanute, M. Am. Soc. C. E.—A number of questions have been asked which I should like to answer concerning the report of the Committee on the Preservation of Timber, but it is getting late, and there is other business before the Convention, and I suggest that other discussion be postponed until some future meeting, and that members be requested to present written discussions at that time.

J. N. Tubbs, M. Am. Soc. C. E.—It would be very interesting if the committee would extend their discussion, and make some practical suggestions as to the best methods of encouraging the preservation of our forests; whether it should be done under the control of the General Government or the State, or what should be done to encourage private enterprise in that direction.

Mr. O. Chanute.—I wish to state, in connection with the suggestion just made, that this committee has been at work for five years. It has made the report originally asked for, and it is hoped that the committee will be relieved from further duty, and that whatever action it may be desired that the Society shall take shall be introduced in the form of a new resolution.